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Report

Government of Manitoba,

Water Stewardship

Fisher River Watershed Hydrodynamic Model and Economic Analysis Study

AECOM

Government of Manitoba,

Water Stewardship

Fisher River Watershed Hydrodynamic Model and Economic Analysis Study

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Project Number:

F685 002 04 (4.6.1)

Date:

June, 2009

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Dear Mr. Harrison:

Re: Fisher River Watershed Hydrodynamic Model and Economic Analysis

AECOM Canada Ltd. (AECOM) is pleased to submit twenty (20) copies of our Final Report for the Fisher River Watershed Hydrodynamic Model and Economic Analysis.

Please distribute as required.

If you or the Technical Advisory Committee have any questions or require clarification on any aspects of this report we invite you to call the undersigned at (204) 928-7405.

Thank you for the opportunity to conduct this study and submit this final report.

Sincerely,

AECOM Canada Ltd.

Eric Blais, B.Sc., M.A.
AECOM Water
AJF/dh

(rpt-f685-002-04-fisher river-final-090603-elb.doc)

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Appendix B Community Presentation Response Summary

1. Introduction

The communities within the Fisher River watershed have experienced relatively frequent flooding. The First Nations communities of Peguis and Fisher River believe that flooding is the direct result of land clearing and drainage improvements upstream of their communities. Previous studies have supported these beliefs.

Others in the watershed think that stream channel modifications including the installation of new bridges and low level crossings are factors contributing to flooding. Ice jams at bridge locations frequently result in water level increases above flood stage. Roads paralleling both sides of the Fisher River channel may serve as dykes to raise the in-channel flood peak and may cause increased water depths between the roads while preventing flooding outside the roadways.

These perceptions and others will be examined in this report on hydrodynamic modelling of the Fisher River at Fisher Bay.

1.1 Project Area

The Fisher River drains are located in the Interlake Region of Manitoba. The river has a drainage area of approximately 2,200 km^2 and flows northward and eventually drains into Lake Winnipeg at Fisher Bay.

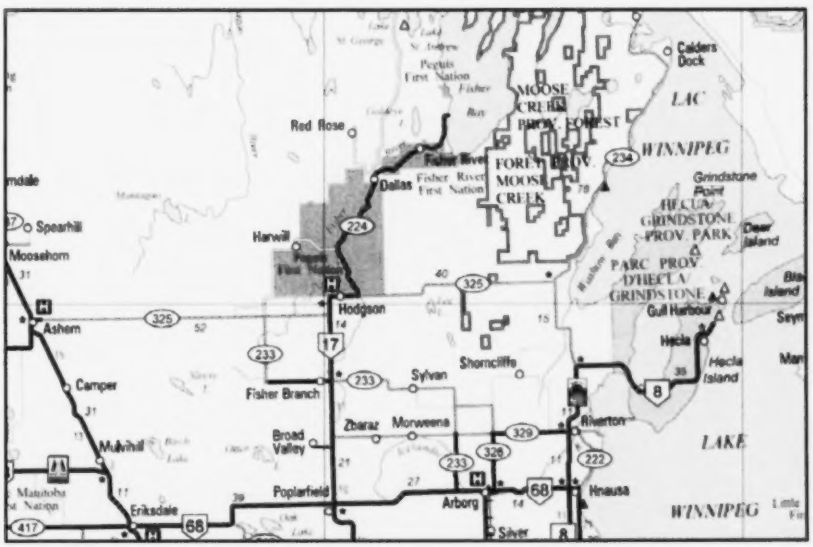


Figure 1.1.1 Study Area Map

Two branches of the Fisher River join together north of Provincial Road (PR) 325, within the Peguis Reserve. The east branch is called the "East Fisher River" while the west branch is simply referred to as the Fisher River. For the purpose of the study the west branch of the Fisher River reach upstream of the

confluence will be called the "West Branch". The channel downstream of the confluence will be referred to as "Fisher River".

Figure 1.1.2 shows the Fisher River watershed on a Provincial Designation of Drain map supplied by Manitoba Water Stewardship (MWS) as part of the Project Request for Proposal. The plan shows all drains to be included in the model.

The Fisher River watershed contains nearly 500 km of drains classified as second order and above. The watershed contains extensive areas of poorly drained land and swamps predominantly in the upper reaches of the west branch but also in tributaries to the main channel of the watershed. Approximately 200 km of drainage has been added since the 1960's.

1.2 Historic Flooding and the Public Perception

Flooding in the Fisher River watershed is primarily the result of a spring snowmelt, with the largest summer flow event ranking as the eighth largest flow event in the 45 years of stream flow recorded at the gauge "Fisher River near Dallas".

Flood damage claims have been made by the Peguis First Nation to the Manitoba Emergency Measures Organization six times in the last nine years totalling more than $4.9M over the period of 1996-2004[1]. In addition, significant funding has been provided by Indian and Northern Affairs Canada (INAC) for temporary flood protection.

The floods of 1974 and 1979 with flows in excess of 100 m^3/s resulted in a total evacuation of the Peguis First Nation while lesser flood such as 1986, 1996, 1997, 2001 and 2004 (with estimated flow of 80 m^3/s) resulted in partial evacuation of the residents.

These events are devastating to these communities. For example, according to the Peguis First Nation the flood of 2004 resulted in 900 people being relocated when 197 homes were flooded and 33 homes and trailers damaged. In addition 28 businesses were affected. The damage to other infrastructure was also severe with 147 locations where water ran over the roads, of which 17 locations washed out completely. After the flood, water was pumped out of residential basements and businesses. Many properties required well water testing and many were found to be contaminated.

[1] According to the Manitoba Water Stewardship Request for Proposals.

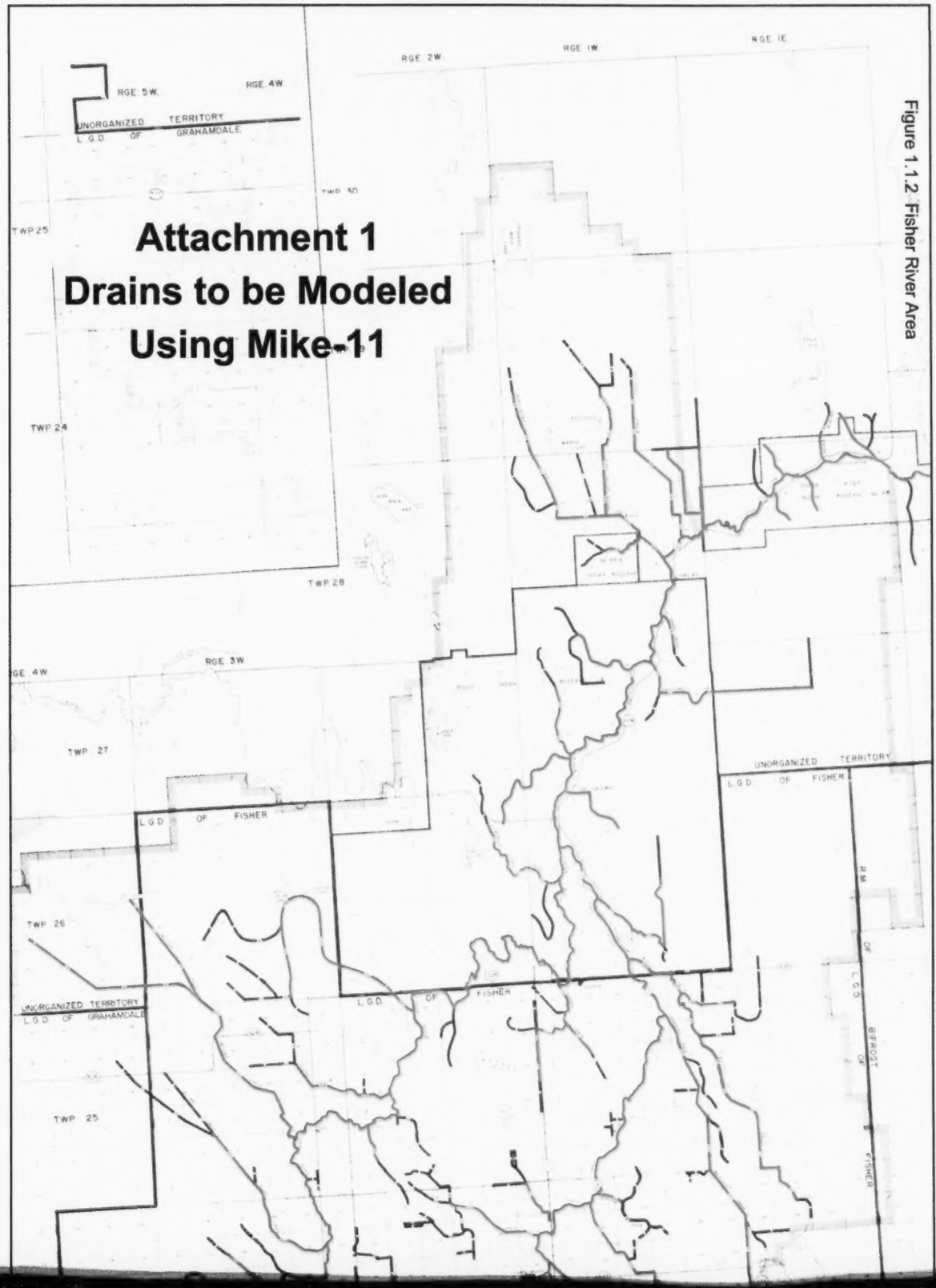
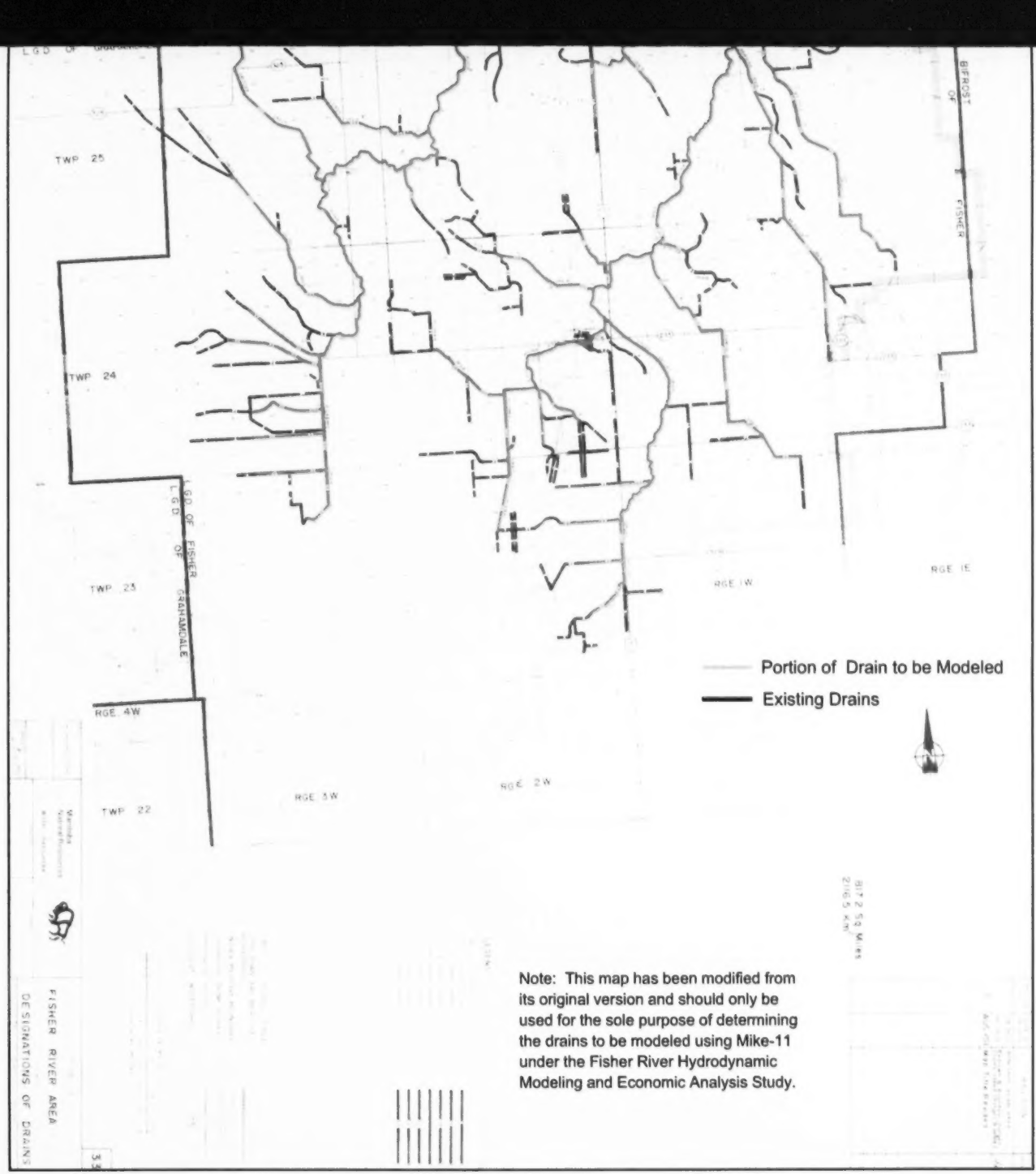


Figure 1.1.2 Fisher River Area


TWP 25
TWP 24
TWP 23
TWP 22
RGE 4W
RGE 3W
RGE 2W
RGE 1W
RGE 1E
L.G.D. OF FISHER
L.G.D. OF GRAHAMDALE
BIFROST
FISHER
Portion of Drain to be Modeled
Existing Drains
Note: This map has been modified from its original version and should only be used for the sole purpose of determining the drains to be modeled using Mike-11 under the Fisher River Hydrodynamic Modeling and Economic Analysis Study.
FISHER RIVER AREA
DESIGNATIONS OF DRAINS

The First Nations cite many concerns associated with flooding and watershed management. These include:

- Loss/damage of property and infrastructure
- Business disruptions due to road restrictions every spring
- Delays in spring seeding of crops severely limiting crop yield
- Road washouts limiting access for emergency vehicles and school buses
- Potential contamination of wells from overland water flows
- Socio-economic disruption
- Disruption of Program/Service delivery
- Community fragmentation
- Evacuation-dislocation of families
- Health concerns related to mould and other bio-contaminants
- Overcrowding for several weeks with associated potential health concerns

Flooding along the Fisher River is not a new issue although the cause has always been contentious. Numerous studies by consultants and government departments have attempted to identify the causes of the flooding or ways to reduce the impacts of floods. Many of these studies were limited in scope and objective and none definitively identified the causes of flooding or economically justifiable flood mitigation. The Prairie Farm Rehabilitation Administration (PFRA) conducted a mapping and flood level analysis in the areas of the Peguis and Fisher River Reserves as early as 1961. Excerpts of previous Fisher River flooding reports made available and reviewed as part of this study were authored by Ed Kuiper [1979], Hydrotek Water Resources Consultants [1982], Trident International Inc. and Applin Associates [1983].

Many people in the First Nation communities have stated a belief that drainage improvements and land clearing in the Rural Municipality of Fisher have contributed to their flooding problems. In this respect they point to the FRED program (Fund for Rural Economic Development) in the 1970's that had reserved funding for the construction of approximately 117 miles of drain in the R.M. of Fisher, although it is unclear from the documents examined how much of this drainage was constructed.

Others in the watershed think that stream channel modifications including the installation of low level crossings and the installation of new bridges are factors contributing to flooding. Ice jams at bridge locations are also common and can result in water level increases if not managed appropriately.

Changes in infrastructure along the river may have contributed to changes in peak water levels. In the late 1970's a design for Provincial Trunk Highway (PTH) 224 was produced that would have raised the road elevation 0.3m above the estimated 100-year flood level. It is evident from current aerial photographs that there are sections of the river where the river is constrained between roads that parallel the river. These roads become dykes and can both raise water levels within the channel and reduce the volume of water entering floodplain storage lateral to the main channel.

1.3 Project Objectives

Due to the sensitivity of flooding this hydrodynamic model study was commissioned by Manitoba Water Stewardship (MWS) to model the hydrology and hydraulic characteristics of the Fisher River and its tributaries. The objective of the study was to identify flood mitigation options and provide the economic analysis to justify the implementation of selected mitigation options. In addition, the study was to determine the causes of flooding and estimate the contribution to flooding from historic land use changes and extension of the drainage network.

Determination of the 100-year flood level and viable mitigation measures will assist rational watershed planning to accommodate community development and reduce flood damages.

The purpose of this report is to describe the hydrologic and hydraulic elements of the MIKE11 hydrodynamic model including its composition and limitations. The report will:

- describe the scope and composition of the model;
- describe the observed and assumed inputs to the model;
- comment on calibration and verification of the model;
- present the results of analysis performed on various flood scenarios to provide insight to the significance of:
    - changes to the drainage system extents since 1966; and
    - changes in land use affecting drainage characteristics;
- compare hydraulic benefits of various flood mitigation options; and
- prepare Benefit-Cost analyses on selected flood mitigation strategies.

1.4 Modelling Approach

The approach used in the study was to develop hydrologic and hydraulic models at the same time. This provided some synergy in the data collection process as both sets of data were organized on a common GIS base. The other important decision reached early in the study was to use summer rainfall events in the development and calibration of the model. Although these events are not as large as recorded spring events it eliminates the uncertainties with snowmelt events. These include the estimation of remaining snow at the time of melt, variability in snow catch and the lack of detailed meteorological data required for an accurate simulation of melt rates.

This approach also eliminates the need to estimate the temporal and spatial variability of ice and ice jams in the channel. The presence of ice alters the stage discharge relationship and would make confirmation of the channel's hydraulic characteristics difficult.

2. Hydraulic Model

2.1 MIKE11 Introduction

The MIKE11 hydrodynamic modelling software was used to model the Fisher River watershed with its complex system of main channel, branches and tributaries. This tool can be used to identify the impact of factors affecting water levels within the catchment, stream channel and floodplain. It is also the appropriate tool to simulate the functionality of proposed flood mitigation options.

MIKE 11 requires inputs representing the physical geography including the stream network complete with road crossings and natural obstructions and topographic surface which becomes the floodplain under extreme events. The model has dynamic boundary conditions represented by runoff hydrographs and downstream lake levels. Hydrographs developed by external tools, are fed into the model as time series files.

The development of any MIKE 11 model is a multi-step process of collecting available data, constructing a sufficiently detailed model, calibrating the model by running known inputs and comparing model results against measurements of water levels and/or flow rates at hydrometric stations or periodic observations at other locations. Verification is accomplished in similar fashion using an independent event. Following satisfactory model calibration, extreme event inputs outside the range of observed events (such as the 100-year flood) can be modelled with some confidence to predict flooding under these conditions.

Development of the MIKE11 hydrodynamic river model and calibration are described in following sections of the report. The first section describes available data sources and the required data processing.

2.2 Data Collection and Model Development

The collection of data for input into the MIKE 11 model involved a number of different activities including analysis and confirmation of plans produced by other agencies, processed LIDAR data collected by the Province of Manitoba and field collection of pertinent information. This included channel cross sections, natural constrictions and man-made obstructions to channel flow such as bridges, culverts, low-level crossings and dykes.

Manitoba land inventory (MLI) and Canada land inventory (CLI) provided GIS data on soil type, land-use, roads and air photos. Manitoba Water Stewardship provided information on the drainage network to model. Manitoba Water Stewardship also provided information on twelve of thirty-four bridge crossings and observed water levels at gauge locations. Manitoba Infrastructure and Transportation (MIT) provided information on nineteen bridges. Some bridges had multiple records from various sources covering the same location. Rainfall records were obtained from Environment Canada. First Nation communities provided economic data in the form of maps and property list and some flood claim data. Details of various public data are described in sections below.

In addition to data describing the general catchment characteristics, an accurate river model requires accurate representation of channel configuration obtained from cross section data and crossing surveys. AECOM conducted field survey of the Fisher River basin from June to September 2006. A total of 333 crossing sites including 49 lateral sites were investigated in the survey. Details of the field program are described in Section 2.7.

2.3 Fisher River Drainage Network

The Manitoba Water Stewardship (MWS) Department supplied a GIS file defining the Fisher River stream network to be included in the model. This included drains up to the second order in the upper watershed. Figure 1.1.2 showed the extents of the drainage network as presented by MWS for modelling.

This network contained approximately 300 miles (480 km) of stream channel including approximately 40.5 kilometres of Fisher River main channel downstream of the confluence between the East and West Branches, 49.1 kilometres of the East Branch, 51.0 kilometres of the West branch and the remainder along 46 tributary branches. The MIKE 11 hydraulic network model of the existing condition extended to the limits shown in Figure 2.3.1 and 2.3.2.

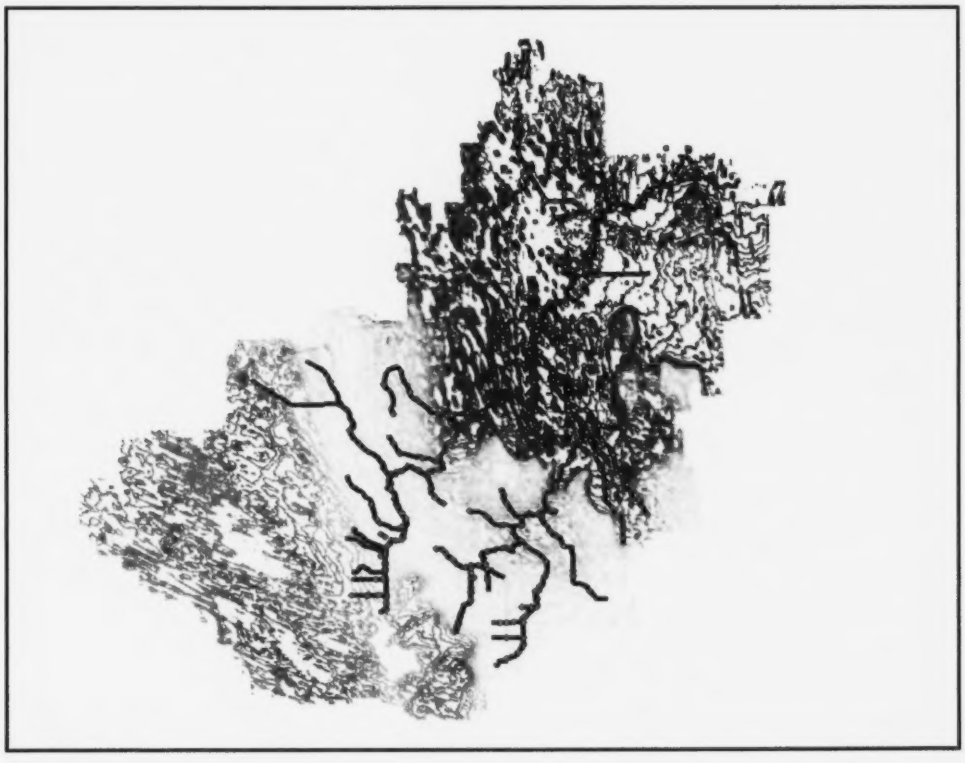


Figure 2.3.1 Fisher River Existing Condition Network on LiDAR Contours

Any extensions to the drainage system extension or channel improvements have the potential to contribute to changes in flooding in the watershed. This contribution and it's effect of the flood peak is dependant on the location of drain improvements and the timing of sub-catchment hydrograph. If the sub-catchment is in the lower main stem and has a short drainage path the sub-catchment peak may arrive before the main stem peak. Alternatively, a sub-catchment in the upper reaches of the watershed may have an extended travel time and arrive after the main stem flood peak. Either situations will add to the flood volume and may extend the duration of the flood but may not contribute to the flood peak.

Some residents of the Fisher River watershed have the perception that improved drainage in the upper watershed has had an adverse contribution to downstream flooding. The use of a hydrodynamic model allows the influence of these dynamic effects to be identified.

The modelling project included analysis of existing data in the basin to determine the extension of drainage development and land clearing since 1966. This was determined from provincial government records of drainage development and land use changes. Relevant photographic material was provided by Water Stewardship.

The drainage system extension was estimated to be in the order of 200 additional kilometres of drainage based on a series of designation of drains maps dating back to the 1960's. The present network model was developed first to facilitate calibration against recent stream flow and level measurements. This allowed the possibility of using the same sub-catchment hydrologic model for both the present and pre-1966 networks. The pre-1966 model represented recently developed drains as unimproved shallow swales with increased roughness, consistent with floodplains, to simulate natural pre-development conditions. A description of the pre-1966 drainage network is shown with undeveloped drains highlighted in Figure 2.3.2.

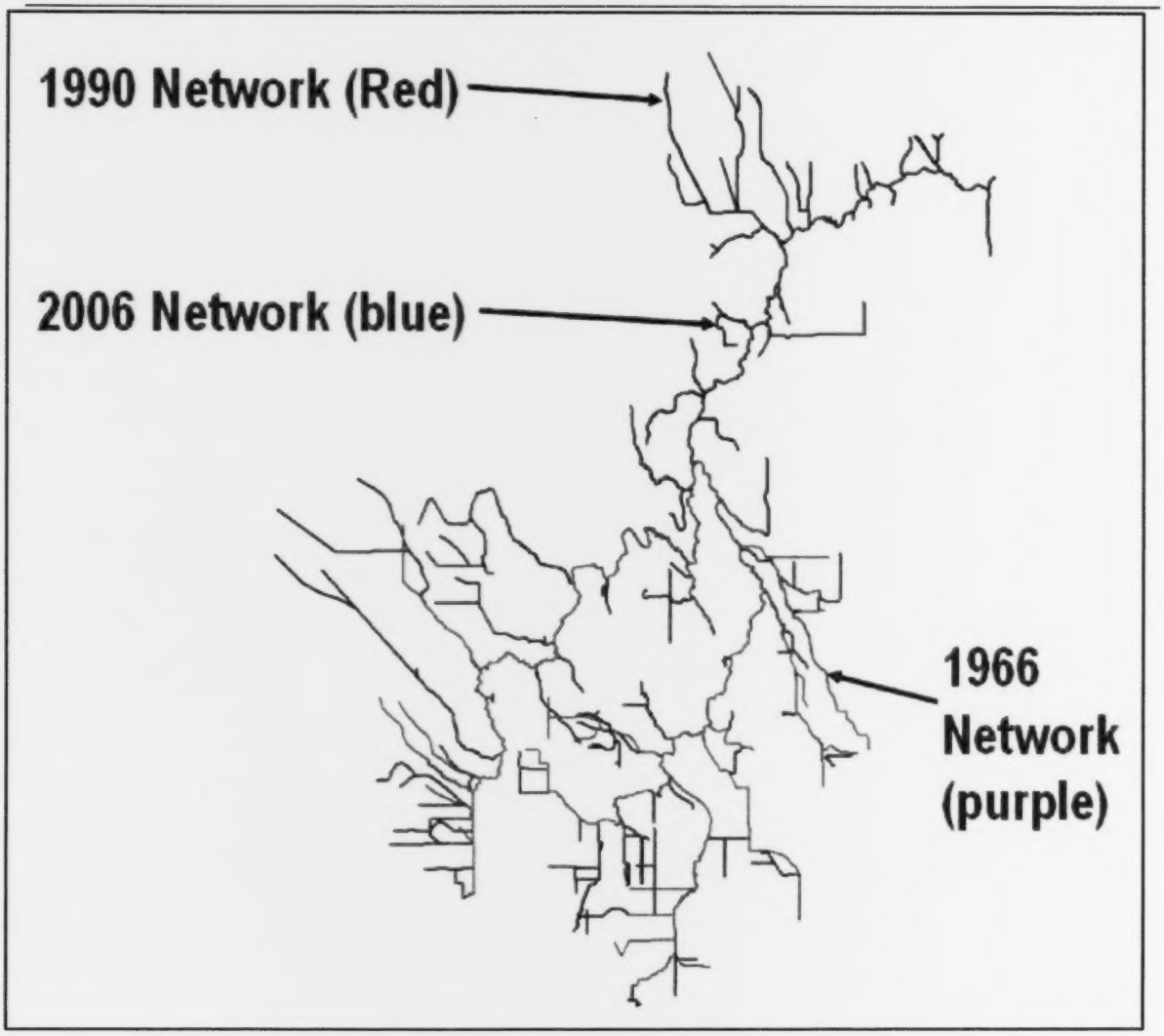


Figure 2.3.2 Fisher River Network (1966, 1990 & 2006)

2.4 River Profile and Cross-Sections

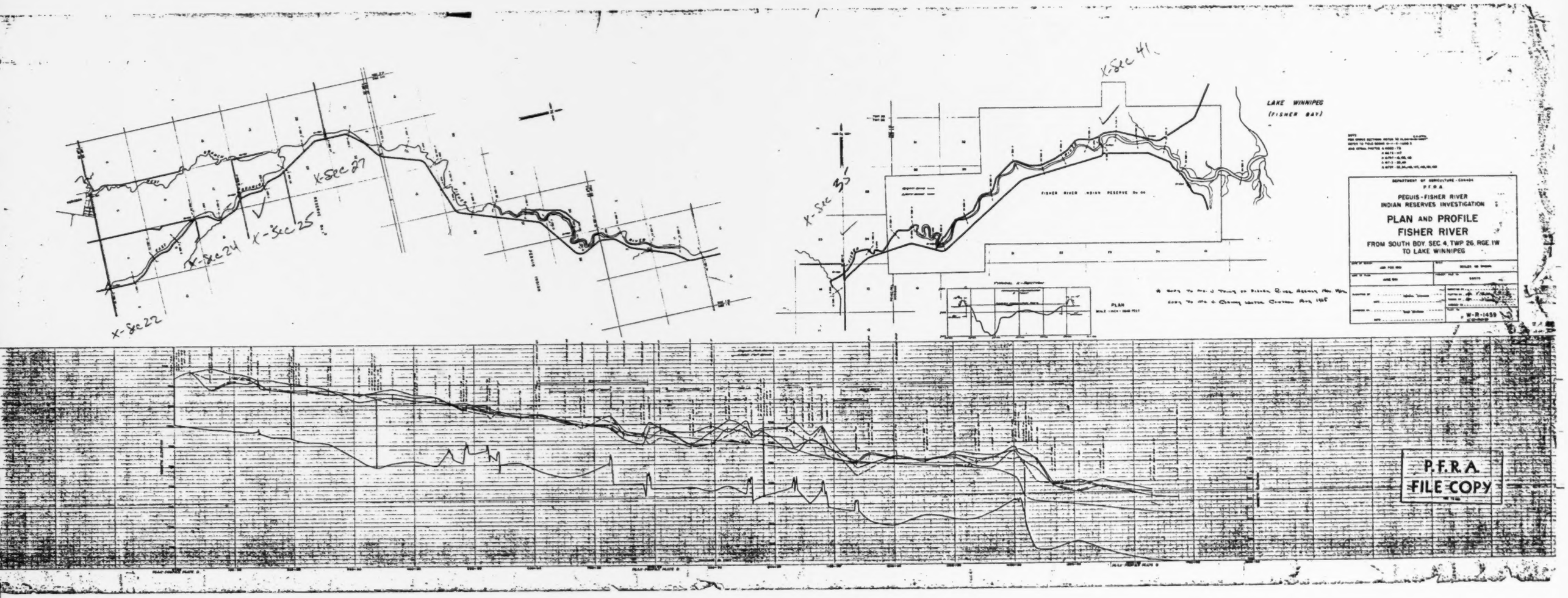
Channel profile and cross-sections were defined from processed Prairie Farm Rehabilitation Agency (PFRA) survey data, MIT and Water Stewardship bridge plans and AECOM-collected field data. First Nation members alluded to the existence of natural constrictions in the Fisher River. Significant constrictions were confirmed and documented by field survey and included in the model. Sufficient information on the floodplain and channel was available to insert the hydraulic controls (i.e. bridges, culverts and low-level crossings) within the drains and along drains and ditches controlling flow to and from the adjacent floodplain.

Manitoba Water Stewardship supplied historic PFRA profile and cross-section information for the downstream portion of the Fisher River within the two First Nations. The historic PFRA profile of the Fisher River (1961) is shown in Figure 2.4.1.

The nominal slope of the river main stem is 0.02%. The upper reaches of the watershed have greater slopes with middle reaches having a flatter grade formed by a natural sill prior to the final steeper reach (0.35%) flowing into Lake Winnipeg. The profile shows numerous locations where natural bed forms such as rapids created slope changes and obstruct efficient flow.

In locations, such as drains in the upper catchment areas, where limited cross-section information was available assumptions were made to simulate stream profile and cross-section extension to the floodplain. Channel cross-section information was provided at crossings surveyed by AECOM (described in Section 2.7). The channel profile was assumed by interpolating points between known culvert inverts. Cross-sections were extended onto the floodplain by applying a shallow grade to a distance representative of the floodplain region.

Figure 2.4.1 PFRA Profile Showing Nominal Slope and Natural Obstructions



KEY PLAN FOR P.F.R.A. 1961 DATA
CROSS-SECTIONS

The Fisher River has notable grade changes along the river course as shown in Figure 2.4.2. The upper reaches of both the West and East Branches are much steeper than the middle and lower reaches. The west branch has a slope of 0.067% from the upper reaches to the confluence. The slope of the east branch is 0.11% from the upper reaches to the confluence.

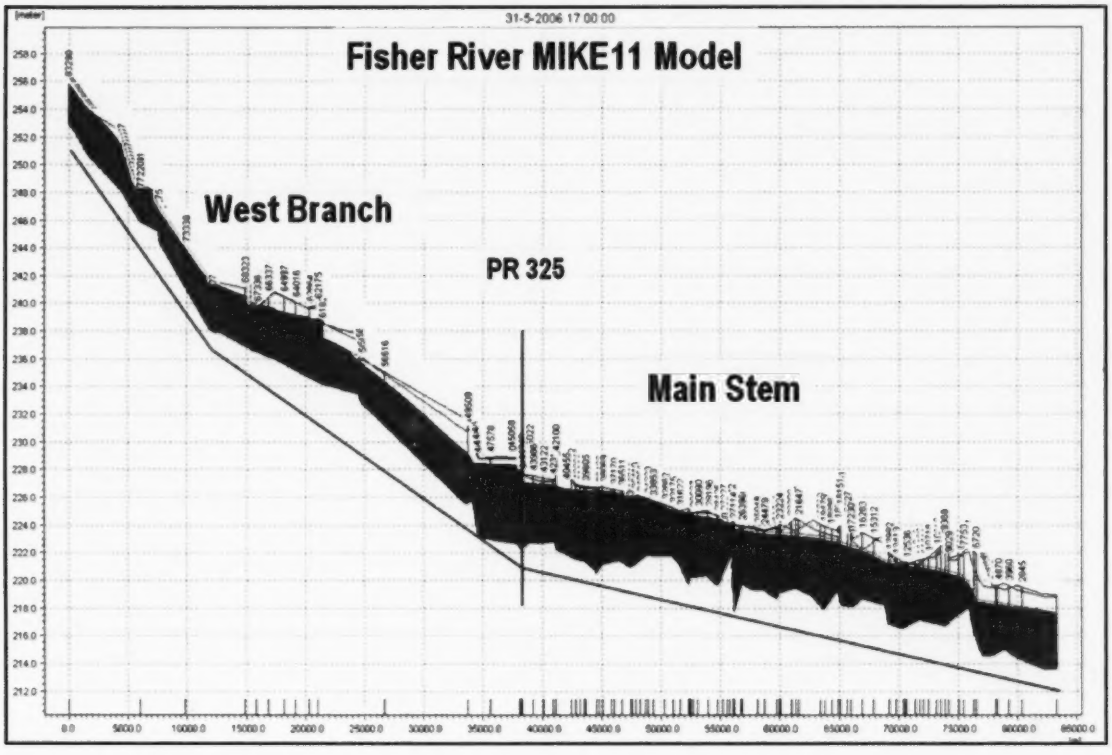


Figure 2.4.2 Fisher River Profile (Upper West Branch to Lake Winnipeg)

Although surveyed cross-section data existed for the Fisher River through the First Nation Lands, previous experience with PFRA data of this age gave AECOM a realistic appreciation for the quality of this data. AECOM developed tools to efficiently process hard copy data and export relevant information into a usable digital form for inclusion in the MIKE11 model.

The cross-section data derived from the PFRA surveys was verified at a few locations. Sufficient agreement was seen between the PFRA historic data and the AECOM-surveyed cross sections so that the PFRA data could be used to construct the main channel model. Figure 2.4.3 shows the verification of PFRA cross section data by comparison to AECOM data. AECOM survey data was collected, processed and geo-rectified with LiDAR elevation data.

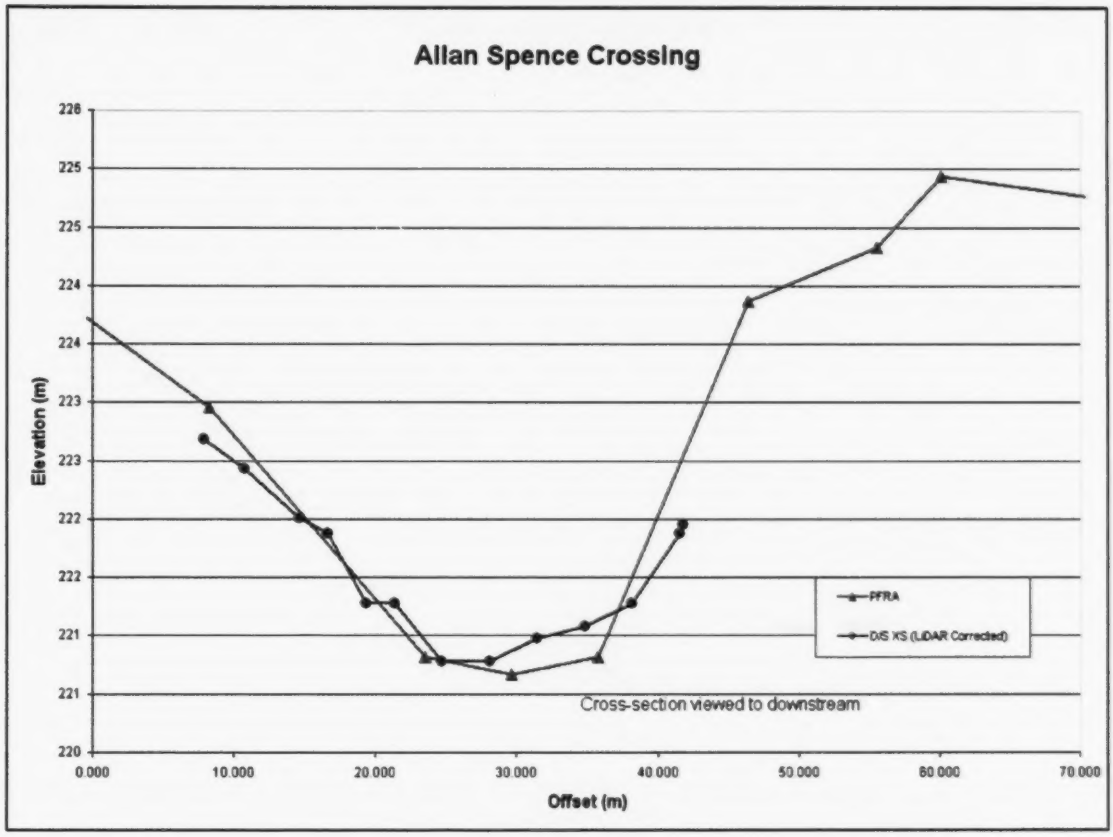


Figure 2.4.3 PFRA Cross Section Verification by AECOM Survey Data

2.5 Surface Topography Data - LiDAR

A digital elevation model (DEM) of the basin topography was produced by LiDAR survey data provided by Manitoba Water Stewardship (MWS). The LiDAR[2] DEM was processed using the MIKE GIS module to define the general topography of the floodplain. The HEC-GeoHMS hydrologic model was used to determine watershed sub-catchments.

[2] LiDAR – (Light Density and Ranging) is the optical analogue of radar which uses intense pulses of laser light to determine the distance (range) to an object or surface

LiDAR information (with a vertical accuracy of approximately 150 mm) was provided by MWS for the Fisher River watershed. This data was provided in two parts with most data collected in 2005-6 and the remainder provided in 2006 during early stages of model development and field data collection.

Fisher River watershed LiDAR data was provided as both processed data and as raw point data. The Province developed a digital elevation model (DEM) mosaic to facilitate computer processing. AECOM filled the gaps using PFRA and AECOM surveyed cross sections. The DEM and other geographic information was used in defining the sub-watershed areas and to compute the runoff characteristics in the hydrologic model.

The LiDAR data was of sufficient quality to provide detailed topographic information on the floodplain. Extraction of accurate cross-section data from small tributaries proved to be too complex and inefficient. However, the LiDAR was used in post-processing to geo-rectify surveyed cross-sections, ditch inverts, culverts or bridge opening elevations and local benchmarks.

AECOM used LiDAR data to better define the floodplain during model construction. Floodplain mapping was important in modelling floodplain storage and to model the potential increase in water levels if floodplain storage were reduced by raising dykes parallel to the river as a flood mitigation scenario.

2.6 Channel Constrictions (Culverts, Bridges, Rapids)

Channel constrictions were found along the river course. Some constrictions were natural obstructions such as natural rock sills, rapids or riffle pools. Others constrictions were man-made such as bridges, culverts, or low-level crossings which had been constructed to facilitate traffic crossing the channel.

Historic and updated bridge plans were obtained from Manitoba Infrastructure and Transportation (MIT) and Manitoba Water Stewardship (MWS) departments. MIT had information only on bridges under the provincial road system. Thirty-four bridge structures existed in the watershed. Nine of the bridges in the modelled streams were documented by MWS. In some instances no bridge design or record drawings were available and AECOM surveyed relevant information at these twenty-five bridge structures as part of the field survey programme.

Analysis of existing bridge design drawings or recorded cross-sections showed significant agreement between historic drawings and AECOM-verified survey information.

Twenty two low-level crossings exist at natural shallow places in the Fisher River and its tributaries. Low-level crossings or "Fords" are traditionally built on rock ridges or other hard stream bed conditions permitting pedestrian or light vehicular traffic to cross the waterway at periods of low flow. Figure 2.6.1 shows the low-level (or "Ford") crossing at the Fisher River Treaty Grounds. Subsequent increases in the level of service expectation required installation of culverts and granular cover to improve access across the river bed during low flows.

Figure 2.6.1 Low-Level (or Ford) Crossing

Low-level crossing structures are prone to overtopping during medium to high flow events and periodically wash out with an associated temporary loss of service. Road and culvert bedding material is transported from the breached culvert crossing is usually deposited downstream in close proximity to the crossing as shown in Figure 2.6.2.

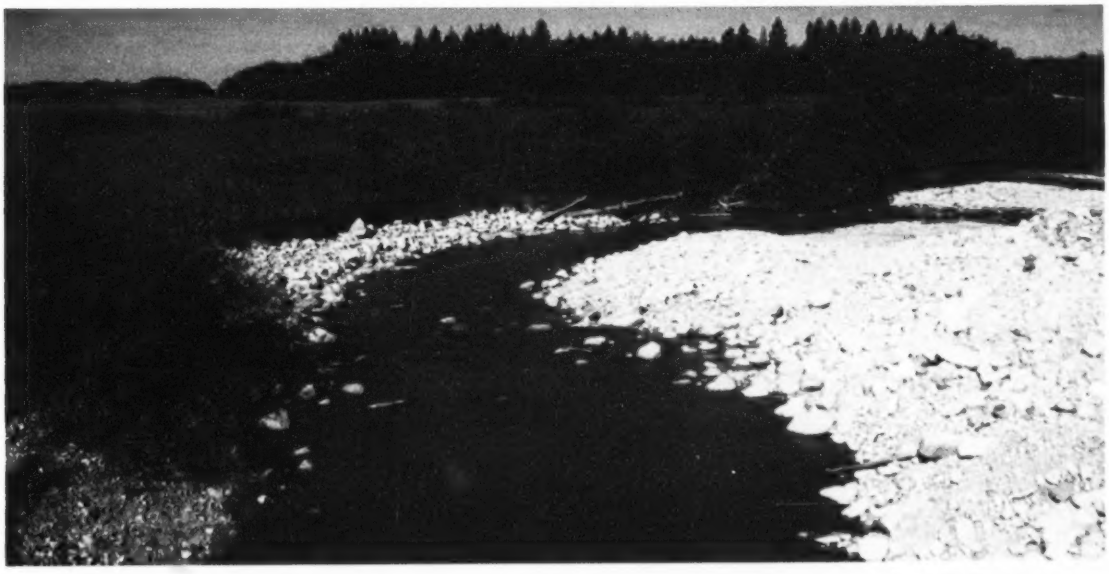


Figure 2.6.2 Granular Deposition Downstream of Frequent Crossing Washout (Ab McPherson's)

Local channel accretion of granular bedding and light armour rock has reduced the channel capacity at some locations. The bed accretion is so significant that water, in the order of a meter or more depth, was pooled in the culvert or upstream river reach. The instability and intermittent nature of these low-flow crossings introduced uncertainty into the modelled riverbed condition and affected calibration efforts.

A realistic hydraulic model requires accurate representation of relevant crossings and stream restrictions. Hydraulic structures (bridges, culverts and low-level crossings) are typically the main hydraulic restrictions within drainage channels. Government representatives were contacted to provide available information on drains, bridges, low-level crossings and culvert locations, dimensions and elevations. Additional data was required to supplement the data available from provincial and municipal sources so a field survey programme was developed to collect sufficient data for comprehensive model construction.

2.7 AECOM Survey Data Collection

Crossing culverts or bridges were anticipated at approximately one drainage structure for every mile of stream channel. AECOM surveyors identified 312 culverts, 34 bridges and 22 low-level crossings on tributaries and main channel.

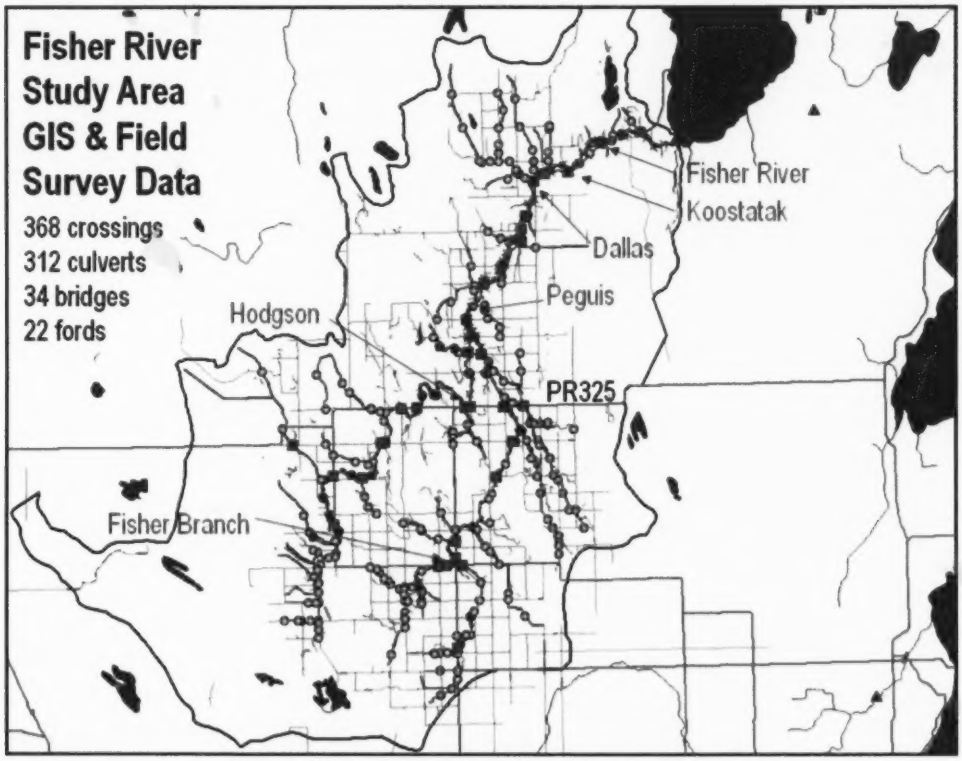


Figure 2.7.1 Fisher River Crossing Locations

At each culvert/bridge site on the main or tributary channel, the AECOM survey team measured the culvert/crossing opening size and length, the channel cross-section dimensions and the road elevation. These elevations were tied into a local datum taken as the road centreline over the centre of the bridge or culvert.

Surveyed cross-section elevations were adjusted to Geodetic elevation by sampling LIDAR data collected in the vicinity of the road centreline intersection over the centre of the bridge or culvert. The LiDAR-rectified cross-section data was entered into the MIKE11 cross-section editor. A few AECOM-surveyed cross-sections were compared to and verified that PFRA cross-sections were still representative and had sufficient accuracy for modelling purposes.

Provincial survey of elevations at the bridge abutments provided additional confirmation that LiDAR elevation samples were consistently within the range considered sufficient for the model's level of detail.

AECOM field records for each crossing were collected, processed and entered into a GIS model for visual analysis by overlay on aerial photographs. Photos, cross-section sketches and annotation on culvert type, end-treatment, flow obstruction by debris and other general condition comments were collected for delivery to the provincial records as part of the project. These records were packaged for delivery to MWS.

Lateral drainage structures were identified at 49 locations through roads that parallel the rivers. These structures allow both distributed flows to reach the river (between defined tributaries) and allow flood flows to leave the channel region to the lateral floodplain. These structures were required to allow more accurate simulation of aerial extent of flooding and allowed flood peak attenuation due to floodplain storage.

Lateral drainage structures were identified at 23 sites in east branch region and 26 sites in west branch region. At each lateral culvert site, the field team measured culvert diameter and length, as well as percent obstruction and condition. Elevations for lateral structures were not tied into the road centreline, so depth below road was estimated from LiDAR ditch inverts, where available, or estimated depth below centreline based on culvert photos comparing culvert diameter and road cover.

2.8 Model Calibration

The MIKE11 model was calibrated to the 2006 flood and verified against the 1984 flood. Both of these events are summer floods which allowed the hydraulic model to function without the added complication of ice in the channel. The calibration process began using steady state flows and static Lake Winnipeg levels for the boundary conditions. This allowed adjustment of the roughness coefficients without the added complication of having to account for water leaving the channel into floodplain storage and potentially causing model instabilities.

Sensitivity to lake level extremes was tested by running the model with the 100 Year Lake Winnipeg water level 722' (220.07m) which included both an estimated setup and an allowance for wave action. It was found that the backwater did not significantly influence water levels more than 8 km upstream of the

first rapids to a water level difference of less than 20 cm. As such it was considered reasonable to simplify the model with a fixed downstream boundary condition. Figure 2.8.1 shows the water surface profile on the lower reach of the Fisher River with Lake Winnipeg boundary conditions set at 220.1m (722'), 219.5m (720') and 217.6m (714'). The Fisher River rapids (Station 7,000) adjacent the Fisher River treaty grounds are evident as steep sections in the water surface profile for all Lake Winnipeg water level boundary conditions. The rapids reduce upstream influence of varied Lake Winnipeg water level boundary conditions as can be seen by the coincident water levels by Station 17,500.

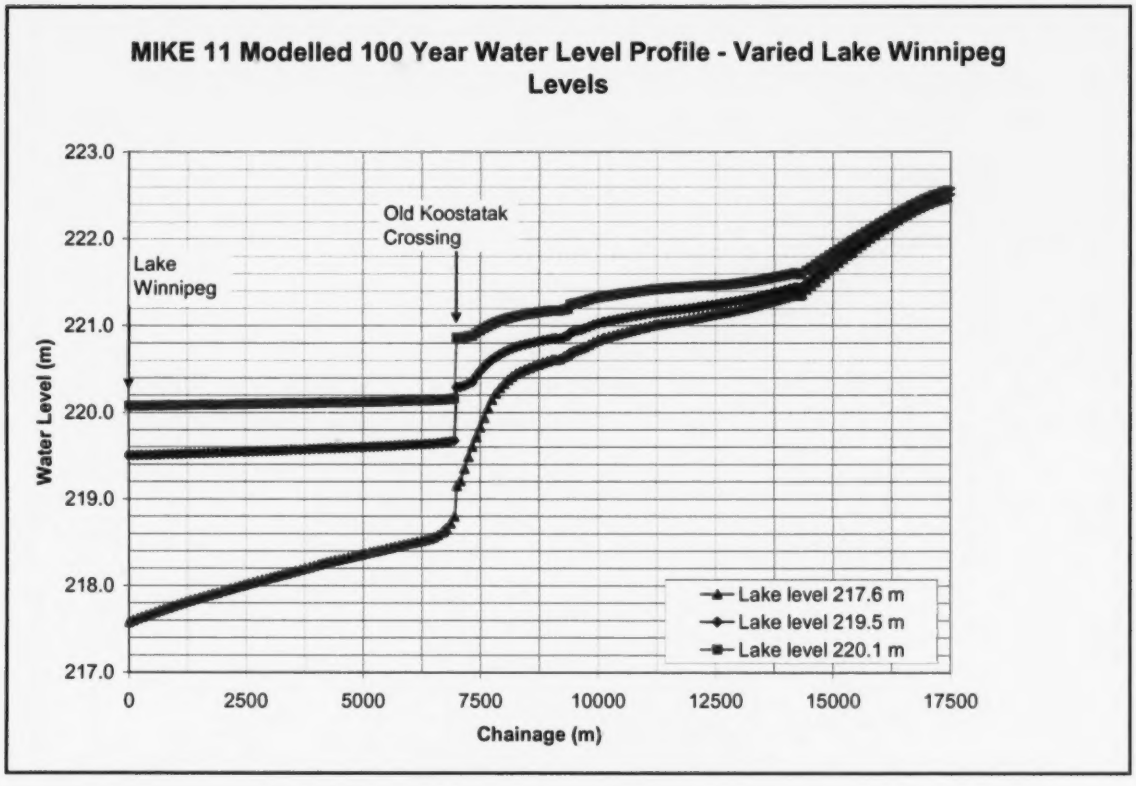


Figure 2.8.1 Hydraulic Profile –with 100-year Flow and Varied Lake Winnipeg Levels

Further discussion of the model calibration and hydrographs follows in Section 3.7 and 3.8.

3. Hydrologic Model

Hydrology is the study of precipitation distribution, antecedent ground moisture and resultant runoff. The goal of hydrologic modelling is to represent the precipitation and runoff from sub-catchments as point source inputs to the hydraulic model.

Rainfall records for the region are analyzed to determine the rainfall event with a selected statistical return period. Sub-catchment characteristics of area, channel length, average basin slope, soil type and land use are gathered as input to the hydrologic model. These are used to compute the time of concentration and Soil Conservation Service (SCS) curve number. Sub-catchment hydrographs are generated from these parameters and rainfall records or estimates applied uniformly over the entire watershed.

Simulated inflow hydrographs are used as the upstream boundary conditions for the hydraulic model. The hydraulic model performs stream flow routing and the resultant modelled water levels and volumes are compared with stream gauge records collected following historic storm events to calibrate the hydrologic model output.

3.1 Prairie Hydrology

In most large Manitoba watersheds, the largest flood peaks occur in the spring and result from the combined effects of snow melt and spring rainfall, rather than rainfall events alone.

The factors affecting snowmelt runoff volumes and rates are more complicated than rainfall and include accumulated winter precipitation, soil moisture at freeze up, spring precipitation and melt rates. The rate of snowmelt is also a function of several factors including temperature, solar radiation, net radiation, relative humidity and wind speed. These factors should be accounted for in modelling snow melt events in order to be able to produce a pattern of runoff that is sufficiently accurate for use in calibrating the hydraulic model.

The two general approaches most used in simulating snowmelt are a relatively simple degree day (or "temperature index") method, and the energy balance approach requiring data on a larger number of parameters. Since a number of the required parameters are not measured within the Fisher River basin and cannot be inferred from stations within a reasonable distance, the energy balance approach was not feasible.

The temperature index method is based on the National Weather Service River Flow Forecast system by Anderson (1973) and was considered more suitable given the available meteorological data. The model uses a simple melt rate dependant upon recorded temperatures above a base temperature to simulate snowmelt. This method does not include many of the factors influencing the spatial variation in the case of the snowmelt process, including the effect of wind and relative humidity on melt rate and the variation in net long and short wave radiation acting on the snow pack due to differences in vegetation cover.

Detailed hydrologic modelling of snowmelt events has always been difficult in large Manitoba watersheds like the Fisher River. This is primarily due to the lack of detailed meteorological data (solar radiation, wind, relative humidity, etc) required to develop a sufficiently detailed model.

To overcome this shortfall AECOM used recorded rainfall generated flood events as a proxy for the hydrologic response of the watershed, which still accounted for spatial variation due to differences in land use, drainage and topography.

AECOM evaluated alternative models to produce representative hydrographs from available watershed, environmental and geophysical data. HEC-HMS was preferred due to its transparent modelling algorithms, the available data inputs and the geospatial interface with ESRI products and existing watershed GIS data files.

3.2 Hydrologic Modelling

Estimation of inflow hydrographs for the MIKE11 hydraulic model was achieved through application of HEC-HMS, a Geospatially interfaced hydrologic model system. HEC-HMS is a software product developed by the Hydrologic Engineering Centre (HEC) a branch of the United States Army Corp of Engineers (USACE). HEC-HMS is widely distributed, well supported and generally accepted for use throughout North America. Furthermore, the HMS had a large number of tools to use for calculation of precipitation losses and peak timing. Hydrologic outputs from the model were verified against provincially accepted regional hydrologic methods.

Application of hydrologic modelling requires a number of physical parameters. The catchment and sub-catchment areas must be estimated. This estimate is based on the available topography; stream and catchment slope; catchment shape and aerial extent of potential storage and location within the sub-catchment as well as soil type and land-use which must be represented to determine runoff characteristics. Stream slope is derived from ground surface and stream bed elevations.

Hydrologic modelling calibration requires rainfall records from the catchment as inputs. Rainfall for a given event was assumed to be uniformly distributed over the catchment due to insufficient rain gauge records.

The Fisher River watershed contained four rain gauges with historic data. These gauges were: Fisher Branch; Fisher Branch (AUT); Fisher Branch South; and Hodgson 2. Hodgson 2 gauge data was discarded as it contained rainfall patterns that were dissimilar to the other three gauges.

Hydrologic modelling produced 148 hydrographs representing upstream and lateral inflows which were routed through the network of streams in the MIKE11 model. Stream flow routing was performed in the MIKE11 hydraulic model where water levels and volumes were quantified and compared with stream flow records resulting from historic storm events. Through this iterative process the hydrologic model was adjusted to represent the physical watershed and produce discrete hydrograph inputs for each sub-catchment in the watershed model.

The province of Manitoba has developed a Regional Hydrologic method which is built on stream flow measurements collected at various gauge locations. These records were used in combined calibration of the hydrologic and hydraulic models and are described further in Section 3.3.

A second goal of detailed hydrologic modelling was to quantify the impact of changes in land-use and soil cover within the watershed due to agricultural development and drainage improvements. Once the hydrographic inflows were calibrated to represent the existing land use they were modified to represent pre-1966 land use conditions. Section 7.0 provides comment on the degree to which the model was able to quantify the impact of changes in the watershed.

3.2.1 Initial Hydrologic Observations

Most large floods within the Fisher River watershed occur as a result of spring melt events. Meteorological and corresponding flow records are presented in Table 3.2.1.

Peak flows on the East Fisher River are proportionally larger per unit area than the West Branch or the watershed as a whole. The East Fisher River near Hodgson represents only a quarter of the total watershed area (above the gauge near Dallas) but the peak flows in high flow years are about 60% of what is observed at the gauge at Fisher River near Dallas.

The Fisher River watershed requires approximately 180mm (7 inches) of precipitation to produce a major flood. The flood peak that results is variable depending on the melt rate during the melt period and the distribution of precipitation.

The examination of precipitation and flow data identified an anomaly in the data. The recorded flow in 1986 does not follow the usual pattern of proportionality between the peak flow on the East Fisher River and the Fisher River near Dallas. In addition, the recorded precipitation does not appear to be sufficient to produce a major flood. The historic flow records revealed an abnormal pattern of flows with a more pronounced peak in flow and ice conditions persisting until after the peak flow.

Table 3.2.1 Seven Largest Flow Events at Fisher River near Dallas

Year	East Fisher River (393 km^2)		Fisher River nr Dallas (1710 km^2)		Lag days	East Fisher as % of nr Dallas (23% by area)	Precipitation at Fisher Branch		
	Peak Flow m^3/s	Date	Peak Flow m^3/s	Date			Nov-Mar (mm)	Apr to peak (mm)	Total (mm)
1979	70.8	April 23	119	April 23	0	59%	168	59	226
1974	64.8	April 20	105	April 22	2	62%	192	18	210
1986	33.8	April 1	87.4	April 4	3	39%	150	0	150
2001			87.2	April 13			203	12	215
1976	61.2	April 7	85.2	April 9	2	72%	146	38	184
2004			83.4	April 18			241	21	262
1998			77.7	April 15			171	55	226

The request for proposal suggested that the runoff events from 1979 and 1986 were to be used for hydrologic model calibration, and the runoff events from 1974, 1976 & 2004 were to be used for verification. The events identified for calibration and verification were all found to be snowmelt events. This was not surprising as there has only been one rainfall generated annual peak flow of any significance in the period of record. The 1986 runoff event was found to be an anomaly year with changes in peak flow output due to dry antecedent conditions.

The entire flow record was examined and the suitability of these years analysed. Figure 3.2.1 shows the annual peaks for the period 1961 to 2007. Water Stewardship suggested the annual events (or years) to use for model calibration and verification. Upon analysis of these events, the suggested events presented complexities so that alternate years were suggested for model calibration and verification. Proposed changes were approved by Water Stewardship staff. Water Stewardship provided available water level and flow data for the Fisher River Gauge at Dallas and the East Fisher at PR 325.

An examination of the annual peaks from the early 60's to present illustrates patterns of high flow events corresponding to the wet years, and dry periods with less frequent significant flood events.

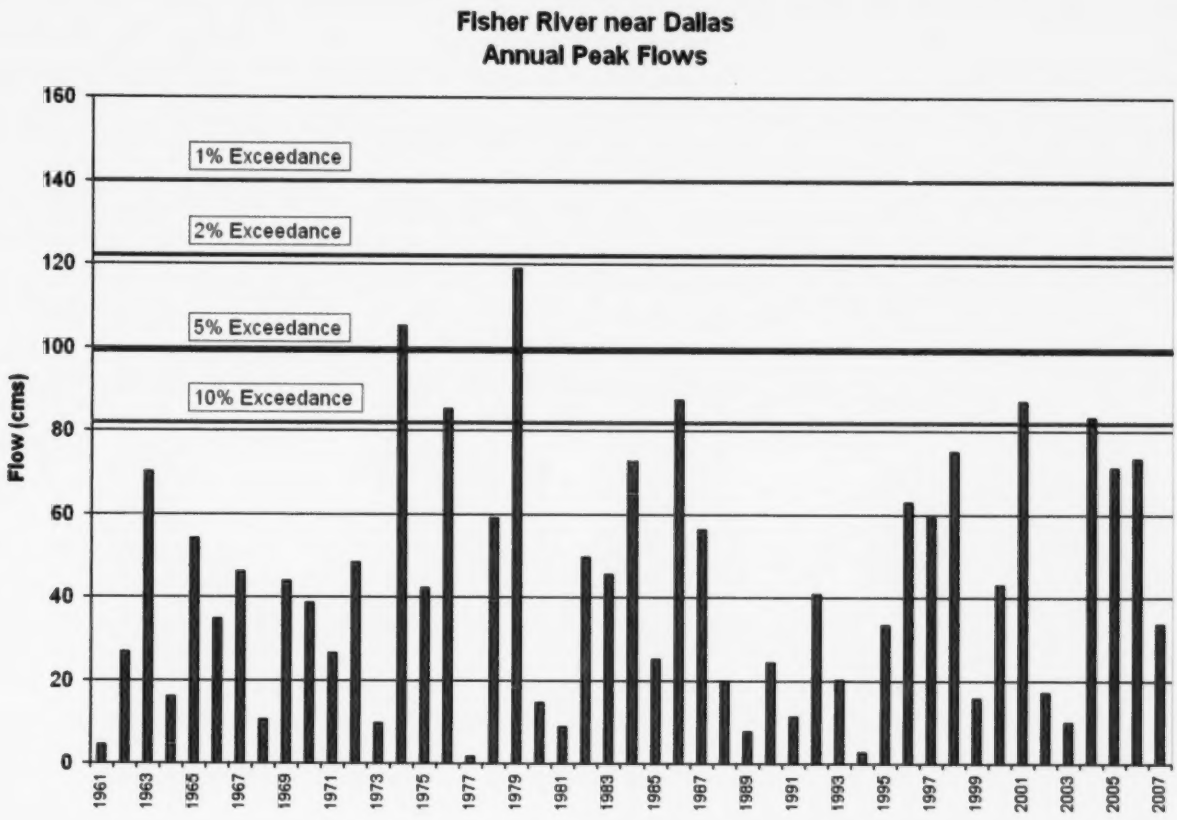


Figure 3.2.1 Annual Peaks for Period 1961-2007

3.3 Flood Frequency Analysis

Fisher River stream flow estimates from Water Survey Canada were available for two gauges in the Fisher River basin. The primary gauge is "Fisher River near Dallas" (05SD003) which records levels on a continuous basis and is the location where flow metering is conducted to verify flow estimates. Periodic water level records are typically collected at "East Fisher River at Hodgson" (05SD004) to capture the spring flood rising limb and peak. In addition, peak water level records have been collected at main stem bridges for various flood events. These records were used in combined calibration of the hydrologic and hydraulic models.

The province of Manitoba has developed a Regional Hydrologic method which is built on stream flow measurements collected at various gauge locations. Table 3.3.1 shows the Regional Method values used to generate flow predictions.

Table 3.3.1 Manitoba Regional Flood Formulae (MWS)

REGIONAL FLOOD FORMULAE
ZONE 3
Q(CMS)=C*AREA(SQ.KM.)**N
0.765
27-Jul-06

STATION NAME	LOCATION	STATION NUMBER	PERIOD OF RECORD	NUMBER OF YEARS	GROSS AREA Sq. Km.	1% Q C	2% Q C	3% Q C	5% Q C	10% Q C	20% Q C	30% Q C	50% Q C
East Fisher River	Hodgson	05SD004	1961-1974, 1976-1997 R	47	394	88.5	75.5	67.9	58.4	45.5	32.7	25.3	16.0
			1958-1960,1975,1998-04 C			0.915	0.781	0.702	0.603	0.470	0.338	0.262	0.165
Fisher River	Dallas	05SD003	1961-2004 R	47	1480	140	123	112	99.1	81.0	62.6	51.4	36.4
			1958-1960 C			0.527	0.461	0.421	0.372	0.304	0.235	0.193	0.137
Fisher River	Peguis	FISHER	1959-1991 Calc	32	1480	180	153	138	118	91.8	66.2	51.4	32.8
						0.675	0.574	0.519	0.443	0.345	0.249	0.193	0.123

Manitoba Water Stewardship provided flood frequency analysis for the Fisher River basin. The flood frequency analysis for Fisher River near Dallas gauge (05SD003) is shown in Figure 3.3.1. Based on this curve and communications with the province, the flood event with 1% probability of exceedance (100-year Flood) is estimated as 138 m^3/s.

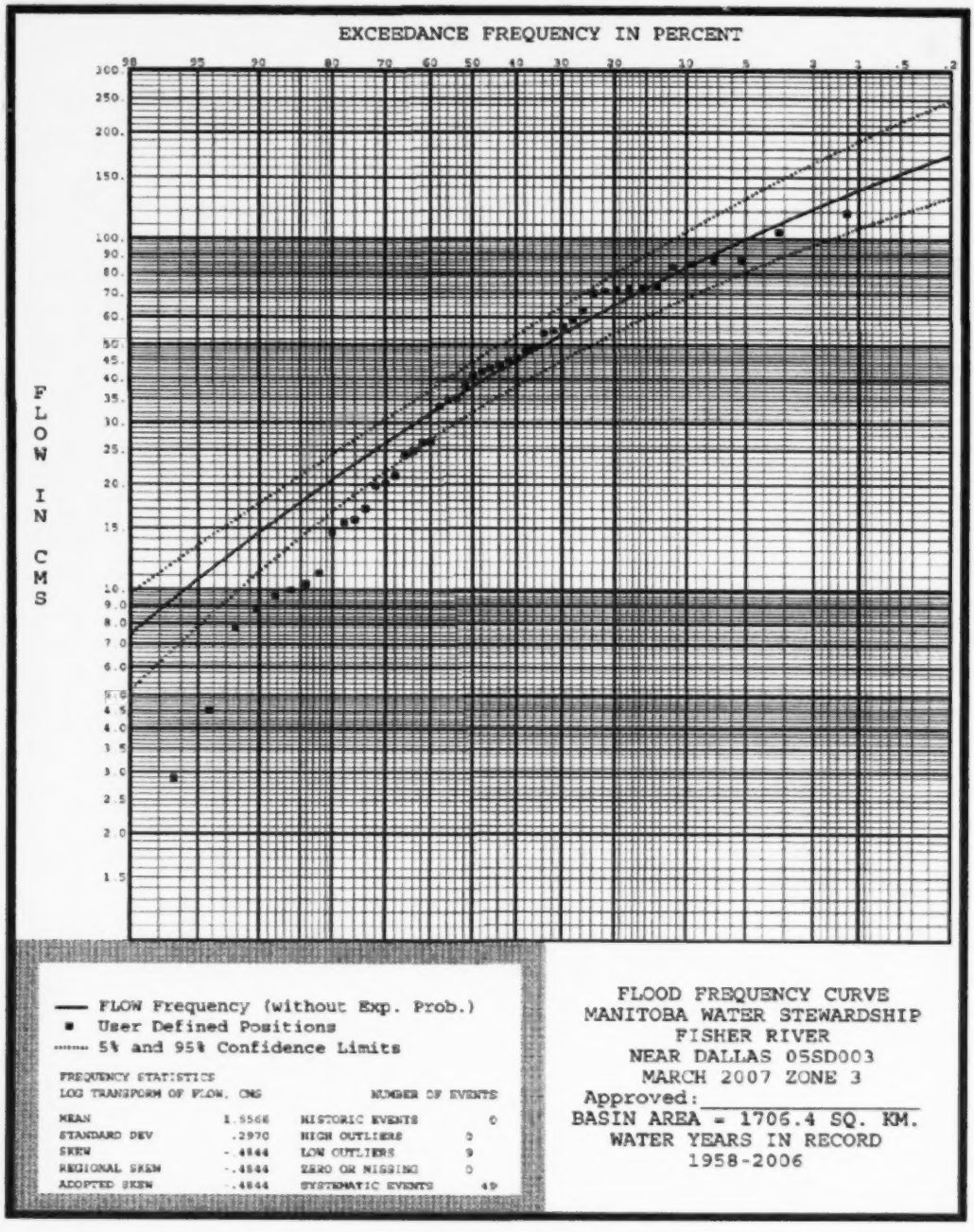

EXCEEDANCE FREQUENCY IN PERCENT
98 95 90 80 70 60 50 40 30 20 10 5 2 1 .5 .2
FLOW IN CMS
300 250. 200. 150. 100. 90. 80. 70. 60. 50. 45. 40. 35. 30. 25. 20. 15. 10. 9.0 8.0 7.0 6.0 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5
FLOW Frequency (without Exp. Prob.)
User Defined Positions
5% and 95% Confidence Limits
FREQUENCY STATISTICS
LOG TRANSFORM OF FLOW, CMS
MEAN 1.5566
STANDARD DEV .2970
SKEW -.4844
REGIONAL SKEW -.4844
ADOPTED SKEW -.4844
NUMBER OF EVENTS
HISTORIC EVENTS 0
HIGH OUTLIERS 0
LOW OUTLIERS 9
ZERO OR MISSING 0
SYSTEMATIC EVENTS 49
FLOOD FREQUENCY CURVE
MANITOBA WATER STEWARDSHIP
FISHER RIVER
NEAR DALLAS 05SD003
MARCH 2007 ZONE 3
Approved:_____
BASIN AREA = 1706.4 SQ. KM.
WATER YEARS IN RECORD
1958-2006

Figure 3.3.1 Flood Frequency Analysis Fisher River Near Dallas Gauge #05SD003 (MWS)

3.4 Watershed Description

The Fisher River basin is nearly 2200 km^2 in size with 1710 km^2 upstream of the Fisher River gauge at Dallas. The basin is generally sloped toward the north east where the Fisher River flows into Lake Winnipeg. The upper reaches of the watershed are more steeply sloped with flatter slopes in the lower reaches as noted earlier in Section 2.4.

The basin geology has been influenced by glacial formation. Glacial depositions of till, sand and silty clay materials overlie a limestone foundation. The till depositions lie in northwest to southeast direction, causing drainage in some portions to flow in long meandering paths northwest and southeast before proceeding in the north east direction of the main channels. Occasional outcrops of the underlying rocks increase the incidence of perched marches and are found in lower reaches of the river as rapids.

LiDAR information was provided by the Manitoba Water Stewardship department to assist in development of a digital elevation model (DEM). The DEM was the basis of the watershed contour map shown in Figure 2.3.1.

Figure 1.1.2 shows the existing (2006) Fisher River drainage network to be modelled with the drains defined by the province as Order two (2) and greater. Some Order (1) one drains were also included by the province in the streams to be modelled.

Current system of improved agricultural drains and natural stream included in the model had a total length of 421 km. The pre-1966 drainage network was estimated to have a total length of 200 km less than at present. The AECOM model simulated the pre-1966 drainage network by removing 74 km of drain from the MWS-defined model network. The Fund for Rural Economic Development (FRED) gave assistance to local farmers desiring to improve the drainage of their agricultural land. This programme was curtailed when in the 1970's drainage was considered to be a contributing factor in the increased frequency of over bank flooding and impact on communities adjacent to the Fisher River.

The impacts of land-use change and drainage network in the period after 1966 are considered in detail in Section 6.

3.5 Catchment Processing Method

A significant component of hydrologic model success lies in careful delineation of sub-catchments. The first factor to consider in catchment delineation is definition of the model drainage network. The stream network extent was defined by MWS as shown in Figure 1.1.1.

The subsequent step is to define sub-catchments corresponding to the drainage network. One sub-catchment is defined as contributing to the upper end of each drain and a second sub-catchment is defined lateral to both sides of the drain. This lateral catchment is bounded by the upper catchment and by the downstream confluence of the drainage network. Typically these sub-catchments are developed

from available contour information with additional influence given by man-made structures like roads and ditches.

The HEC-GeoHMS computer programme was able to define contributing sub-catchments based on similar inputs as the tradition delineation method. LiDAR data supplied the DEM and formed the topographic basis for the catchment delineation. The existing stream network was burned into the DEM to influence the development of flow concentration to the stream network within the study area. The computer model developed numerous catchments some of which were aggregated to form the total number of catchments practical for input to the MIKE11 hydraulic model.

An early attempt at computerized sub-catchment delineation was made by running the total area of the Fisher River as one complete set. This failed due to the regional extents of the watershed. The elevation variation presented in the large data set was too coarse to allow significant differentiation of subtle elevation changes in the flatter regions of the watershed. The programme failed to process the total watershed sufficiently to define representative catchments so the watershed was parsed into smaller regions.

Eight sub-regions were defined to account for elevation zones and the model was rerun in piece-wise fashion. Boundaries were hard coded into square sub-regions and boundary areas blended together to stitch the total region together.

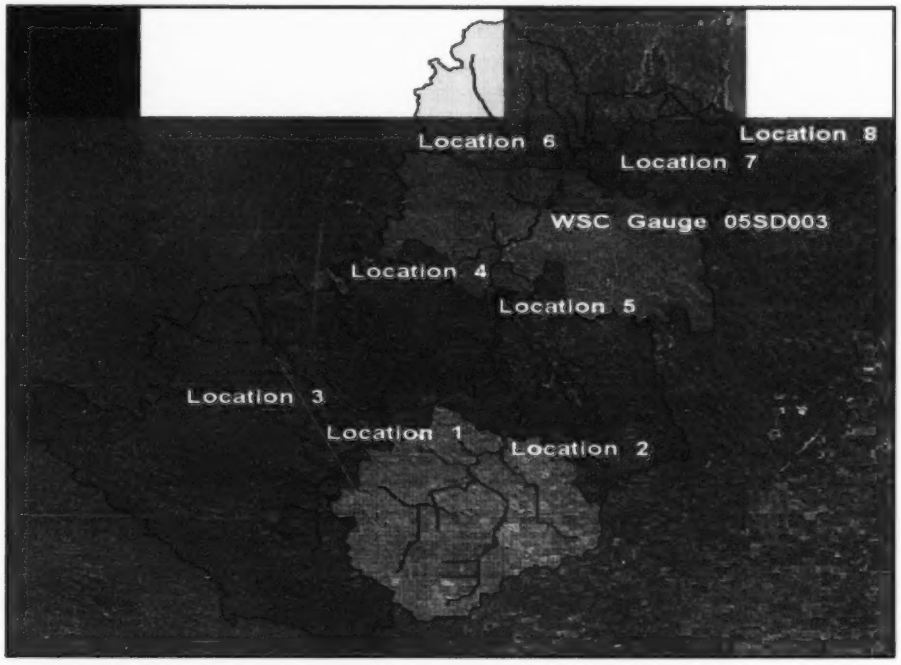


Figure 3.4.1 Fisher River Basin as Eight Sub-Watersheds

Sub-catchments were aggregated within the GIS to match the number of stream tributaries desired in the hydraulic model. One catchment was formed upstream of the upper end of each tributary. One bi-lateral catchment was formed from the sub-catchments on each side of the tributary and aggregated to simulate direct lateral inflow upstream of each tributary confluence with another branch. In total there were 148 catchments formed to represent the whole Fisher River watershed.

Computerized catchment results were compared to the manual delineation performed by the "Traditional Method" of visual review of topographic data and digitization on spatial-based computer tools. A reasonable match was found between manual and computerized output, and confidence gained in the computer model output.

Following catchment delineation, other characteristics were extracted from the catchments based on the GIS sub-catchment polygons and available soil and land use data.

3.6 Soil and Land-Use Modelling

Soil and Land-Use data was gathered from Federal and Provincial sources and developed into a Fisher River Basin Geographic Information System (GIS).

Soil information was downloaded from Manitoba Land Inventory (MLI). Soil type was noted to be predominantly of Silty Clay till with local deposits of sandy ridges and areas of wetland. Organic rich soils are present as are bogs and swamps. Satisfactory metadata describing soil types and their hydrologic drainage characteristics was not found at the data source. Effort was made to specify soil class based on assumptions made on available data, however hydrologic calibration efforts consistently resulted in mismatched hydrographs for observed flow rates generated by historic rainfall amounts. Hydrographs produced from modelling with SCS Hydrologic Soil Groups (HSG) "B", "C" and "D" were consistently too high at the peak runoff rate and volumes were too small for known rainfall inputs.

The soils of the region have been described in previous reports as stony till plain and lacustrine soils. [4]

> "Approximately 65% of the area consists of a stony till plain with many features that tend to restrict its agricultural use. The glacial till is very high in lime carbonate content, having been derived mainly from the underlying limestone rocks. In some places the limestone bedrock is exposed at the surface or covered by only a few inches of glacial drift. The soils belong to the Isafold and Garson associations. They are all very stony and have very thin surface horizons. The other 35 percent of the mapped area consists of a glacial lake basin and terrace area with lacustrine soils of much greater agricultural value. These soils range in texture from sand to clay. Some are imperfectly to poorly drained and degraded

under woods. Over much of the area the lacustrine sediments are thin and are underlain with high-lime till[5]"

Land use information varied both spatially and temporally. Characteristics of land-use were determined from two data sets. The 1966 historic land-use was based on a GIS layer downloaded from the Canadian Land Inventory (CLI). The present land-use was based on a 2002 GIS layer downloaded from the Manitoba Land Initiative (MLI). The historic land use was presented in five classifications, but the modern data was presented with significantly more detail and in 16 classifications. Common classification groupings were selected through discussions with MWS and their provincial hydrologist.

Figure 3.6.1 shows the 2002 classification land use as summarized by MWS.

The areas draining into the west branch of the Fisher River are more woodland and forage crops with significant areas standing as marsh or bog wetlands. Portions of these regions are considered non-contributing (or "ineffective") to peak runoff for small storms of 2-year frequency, however for larger events these areas will contribute both to the peak and to the total duration of floods.

The drainage areas of the Fisher River East Branch are more developed toward agricultural land use due to richer soils and more efficient natural drainage.

Present land use in the watershed is predominantly woodlands 34.8% with agriculture and grasslands forming approximately 17.3 and 29% on better drained portions of the watershed and other uses including marsh, water and built-up areas forming roughly 18.9%.

Soil type, land-use and slope contribute to the selection of representative SCS (Soil Conservation Service) Curve Number (CN). The curve number generally represents the runoff characteristics of the catchment similar to a runoff coefficient. However, HEC-HMS requires a curve number to estimate runoff percent, generate hydrograph time of concentration and calculate infiltration losses. Soil type, land use and slope were considered for each sub-catchment and an aggregate CN calculated based on an area-weighted average for the year being considered.

Details of land-use classification merging and selection of aggregate CN values is discussed in Section 7.3.

Present-day aerial photography describing land use was gathered from the Manitoba Land Inventory (MLI). The 1966 aerial photography was provided by MWS. INAC provided additional high-resolution air photo coverage of the Fisher River and Peguis communities to update residential assets. These photos arrived in early 2008, so these air photos were not used in land use comparison.

[5] Pratt, L.E., Ehrlich, et.al. 1961 Report of Detailed-Reconnaissance Soil Survey of Fisher and Teulon Map Sheet Areas. Soils Report No. 12. Manitoba Soil Survey. Winnipeg.

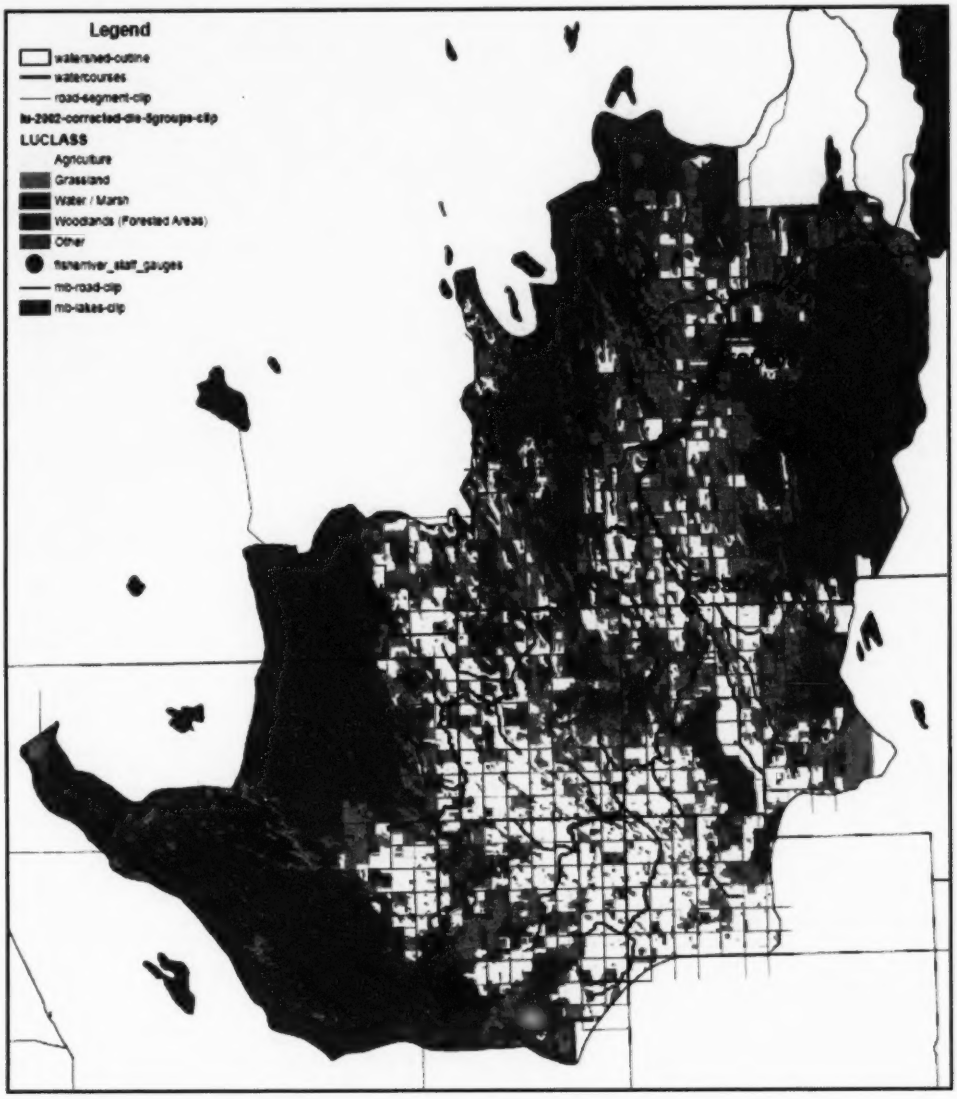


Figure 3.6.1 Fisher River 2002 Land Use Classification (MWS)

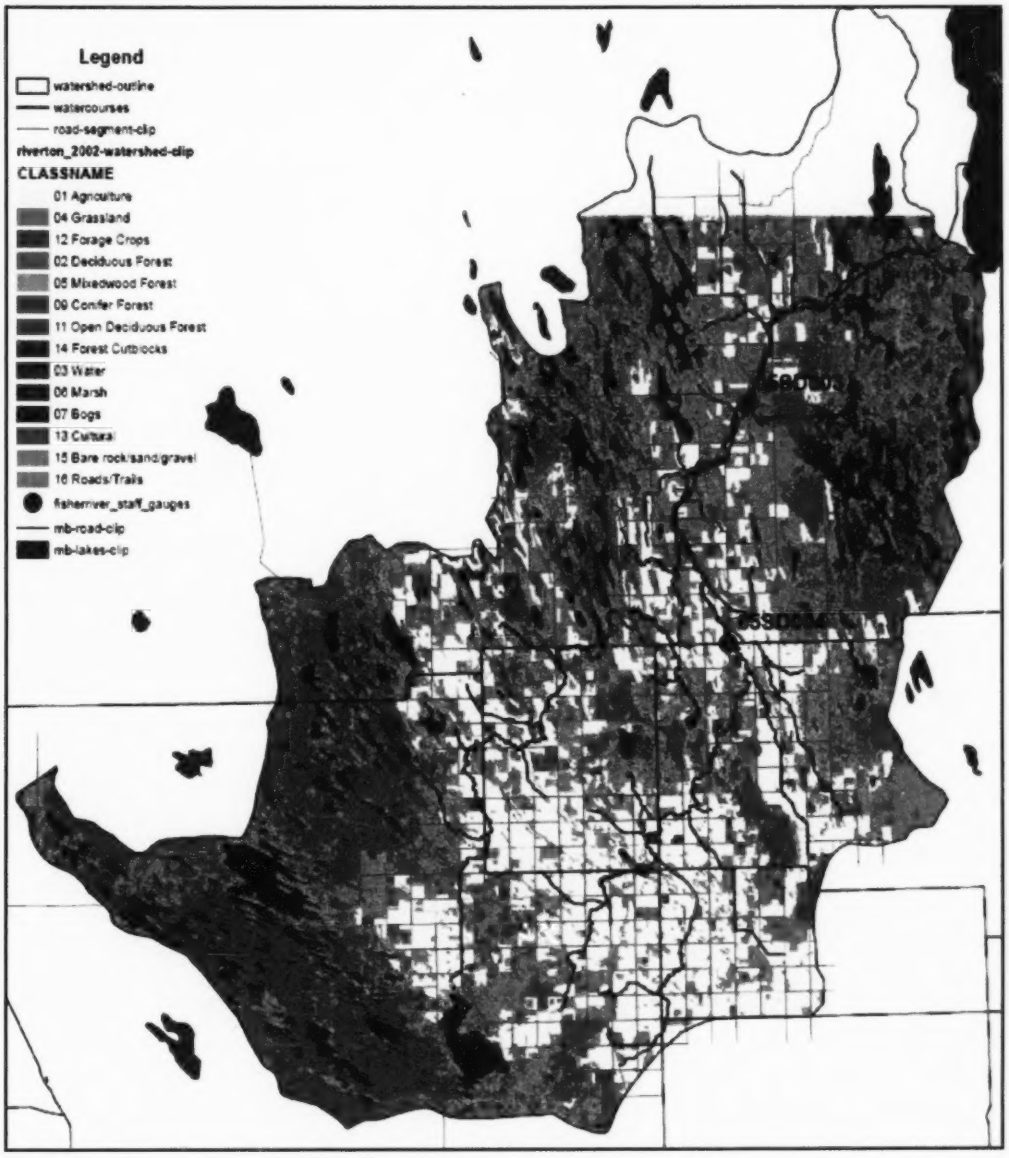


Figure 3.6.2 Fisher River 2002 Land Use Classification

3.7 Hydrograph Timing

HEC-HMS required catchment characteristics to build the hydrologic model. Hydrograph processing was first run using Time of Concentration (T_c) as the basis of sub-basin timing. Sub-regional analysis considered downstream elevation, longest flow path, length of stream and CN. Verification by manual checks and equations confirmed the programme output was reasonable. However, when these hydrographs were input to MIKE11 to consider the influence of routing through the hydraulic model, inconsistencies were discovered. It was found that a flow reversal occurred at the confluence of the west and east branches of the Fisher River under these assumed timing conditions.

Hydrographic processing was run a second time with Storm Duration (T_p) representing sub-basin flow concentration timing. Better fit between MIKE11 model results and observations at the Fisher River gauge suggested this resolved the timing issue and the results appeared reasonable both at the confluence and at the gauge for known storm conditions.

This completed the HEC-HMS development of inputs for hydrograph processing. The next step was to allow HEC-HMS to perform calculations of output hydrographs.

The influences of terrain slope on concentration of flow timing; soil type and land use on infiltration rates; and adjustments to the model time base to fit peak and volume observations is discussed in the following section on hydrograph model calibration.

3.8 Model Calibration

The HEC-HMS generated hydrographs are influenced by the sub-basin model, meteorologic model, control specifications and time series inputs. The basin model contributed elements to define sub-basin catchment area and infiltration characteristics. Evaporation and base-flow processes were not included in this analysis due to insufficient data. Meteorologic model elements were built from the inputs of precipitation and snow melt rate. Control specifications were required to determine how long the simulation should run in total duration and the time interval or time step for computational purposes.

Time series information is required as an input to the hydrologic model. This input had to be built separately from precipitation data collected at local rain gauges. Sufficient precipitation data was available for the 2006 and 1984 events even though not all four gauges had data and some of the data was considered suspect. The model was calibrated to 2006 and validated to the 1984 event.

A sample of sub-catchments were analysed outside HEC-HMS to determine whether the hydrologic model was computing runoff response accurately. Land-use and soil types were incorporated to the model. The precipitation time series was uniformly applied to the catchment. Initially, the simulated depth of runoff was too high with a corresponding exaggeration in runoff volume and flow rate. Adjustments were made to the soil type and a HSG soil type of B uniformly applied to the catchment. The runoff depth resulting from the model based on this soil type adjustment fit more closely to the observed data. Based

on this observation, the HSG soil group was changed to "B" throughout the whole Fisher River basin, with corresponding improvement in hydrologic model response to rainfall.

The sub-catchment hydrographs developed in HEC-HMS based on available sub-catchment characteristics and hydrometric data for input to the MIKE11 model resulted in hydrographs which matched peak flow rates within 3.0 m^3/s (4%) and matched runoff volumes within 604,800 m^3 (1.3%). Figure 3.7.1 below illustrates the hydrographs modelled at the Fisher River gauge compared with the 2006 observations.

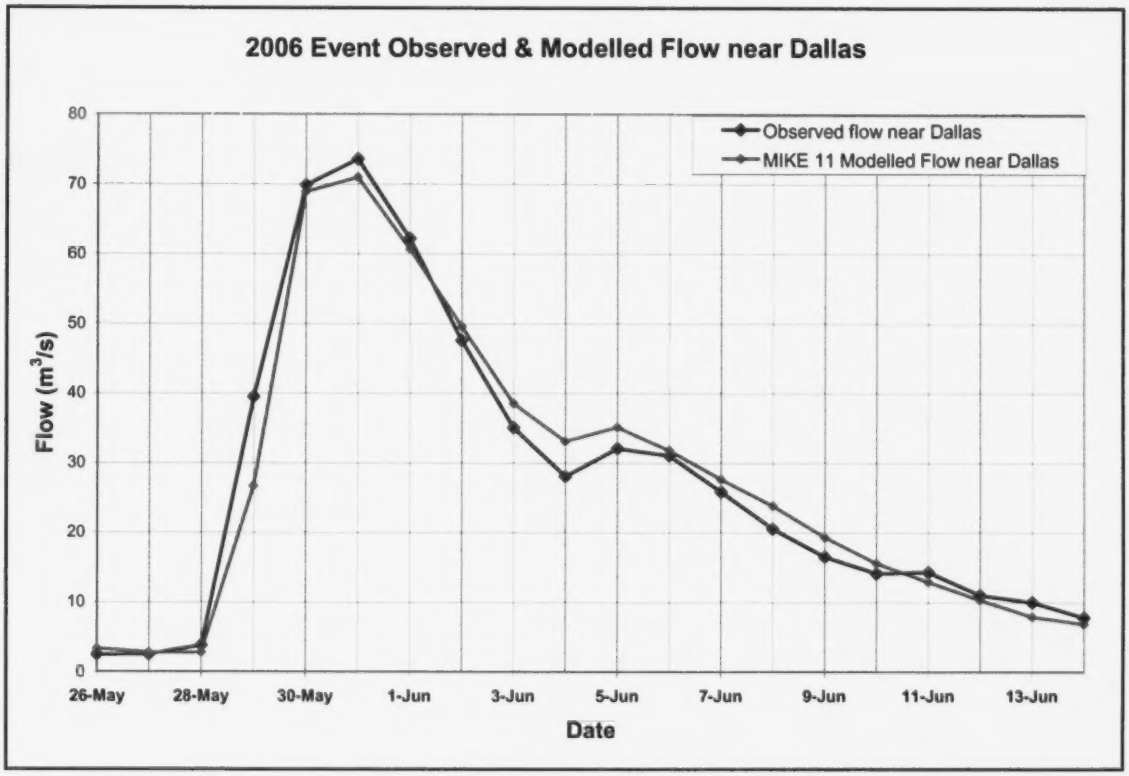


Figure 3.8.1 Fisher River Hydrographs – 2006 Observed and Modelled Flow

Observations of flows and levels at the Fisher River at Dallas gauge was the only gauge location where the model could be checked for accuracy. Some peak flow measurements were available for other lesser events, however the river bed conditions or impact from ice jams on water level was unknown.

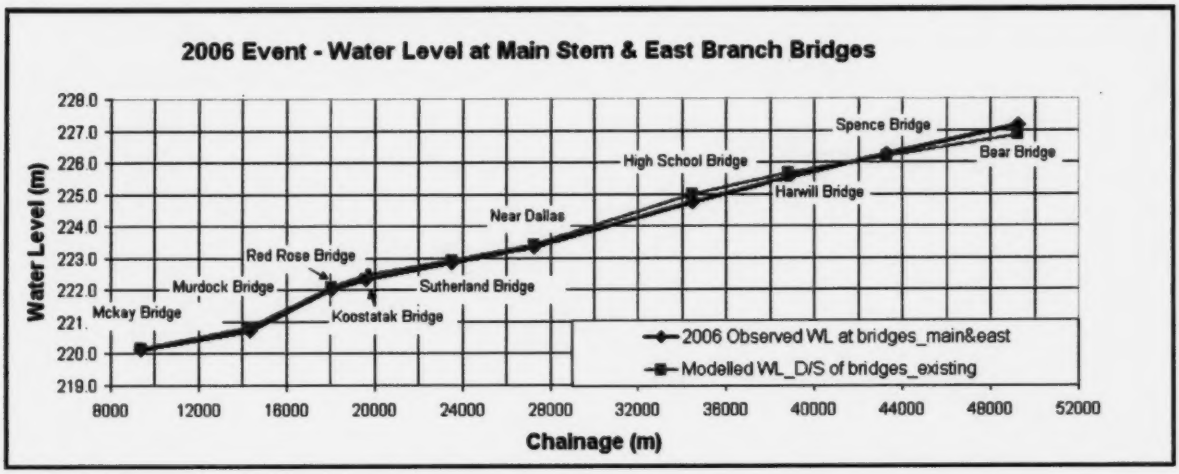


Figure 3.8.2 2006 Modelled & Observed Water Level at Bridges on Fisher River and East Branch

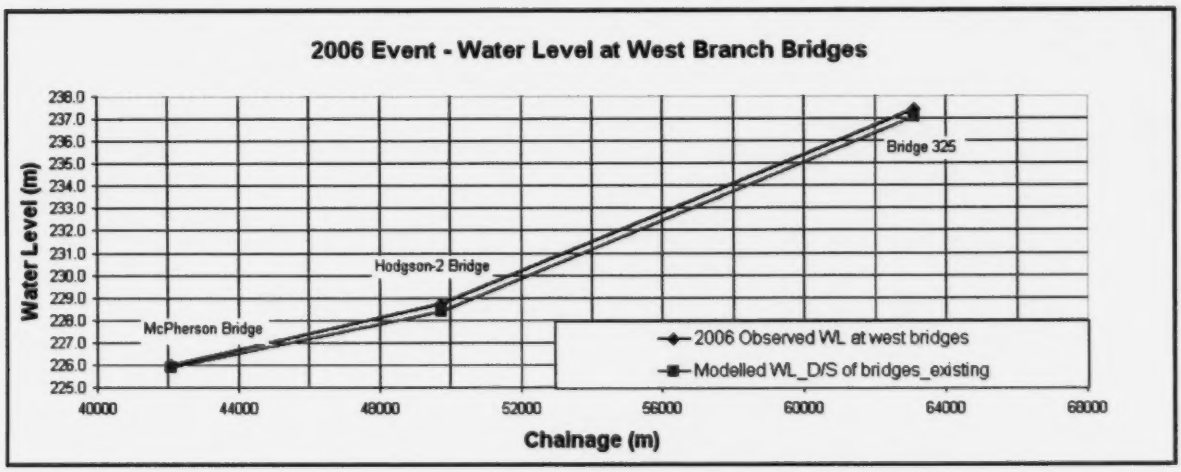


Figure 3.8.3 2006 Modelled & Observed Water Level at Bridges on Fisher River West Branch

Following calibration the combined Hydrographic / hydraulic model was run with an independent input event to verify the model was suitable for modelling other conditions including the design event. The input year selected for verification was 1984. The MIKE11 model was able to match the peak flow and water level within 1.8% for flow and 4.4% for water level. Figure 3.8.4 shows the flow hydrograph and Figure 3.8.5 shows the water level hydrograph.

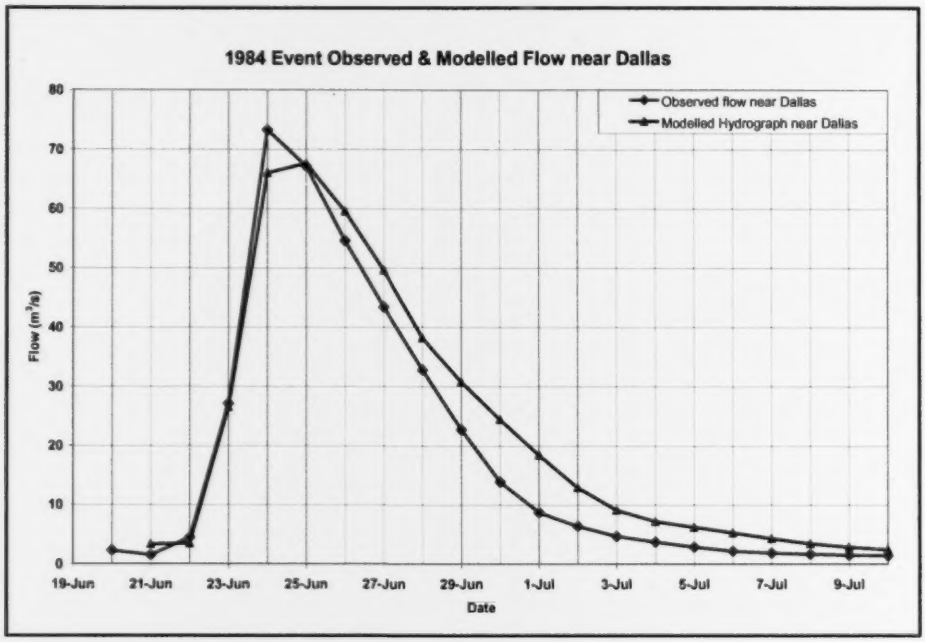


Figure 3.8.4 1984 Modelled & Observed Flow at Fisher River near Dallas

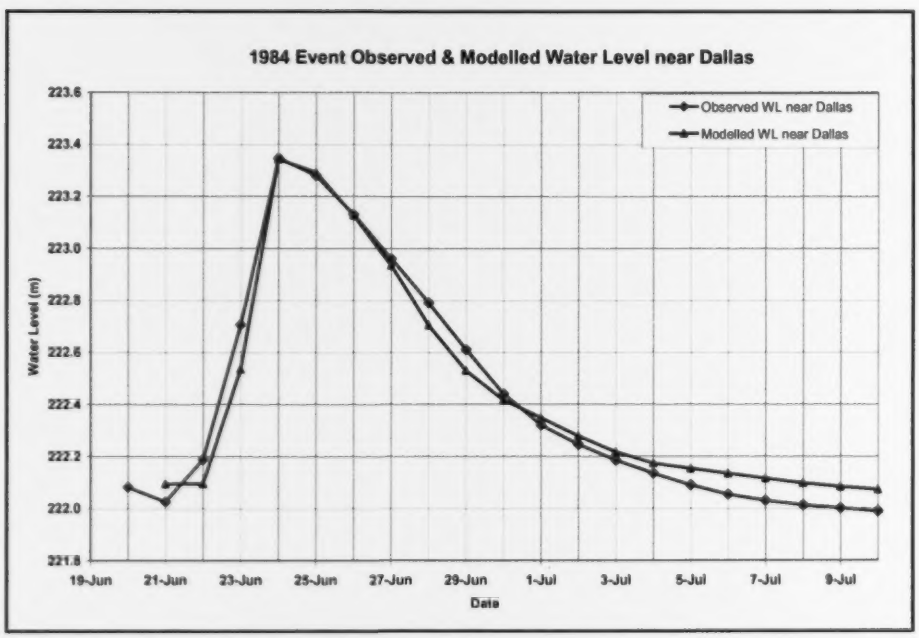


Figure 3.8.5 1984 Modelled & Observed Water Level at Bridges at Fisher River near Dallas

3.9 Development of the 100-year Hydrograph

The calibrated model was used to generate larger hydrographs for modelling the 100-year event. Given that peak flow rates and resultant high water levels were considered the most significant model results, the 2006 hydrographs were scaled up until the estimated 100-year flow rate was achieved at the Fisher River near Dallas gauge. The duration of the hydrograph was held constant to the 2006 event.

Figure 3.9.1 and 3.9.2 below illustrates the 1% event (100-year) hydrographs modelled at the Fisher River gauge.

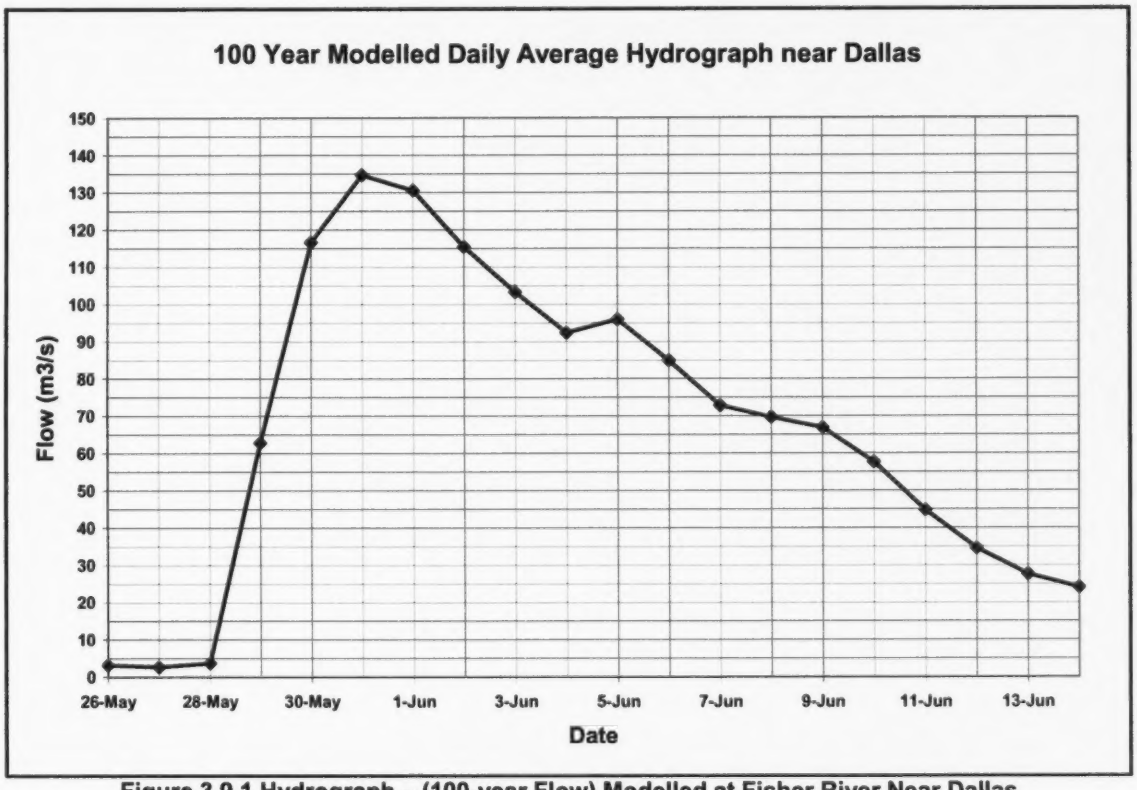


Figure 3.9.1 Hydrograph – (100-year Flow) Modelled at Fisher River Near Dallas

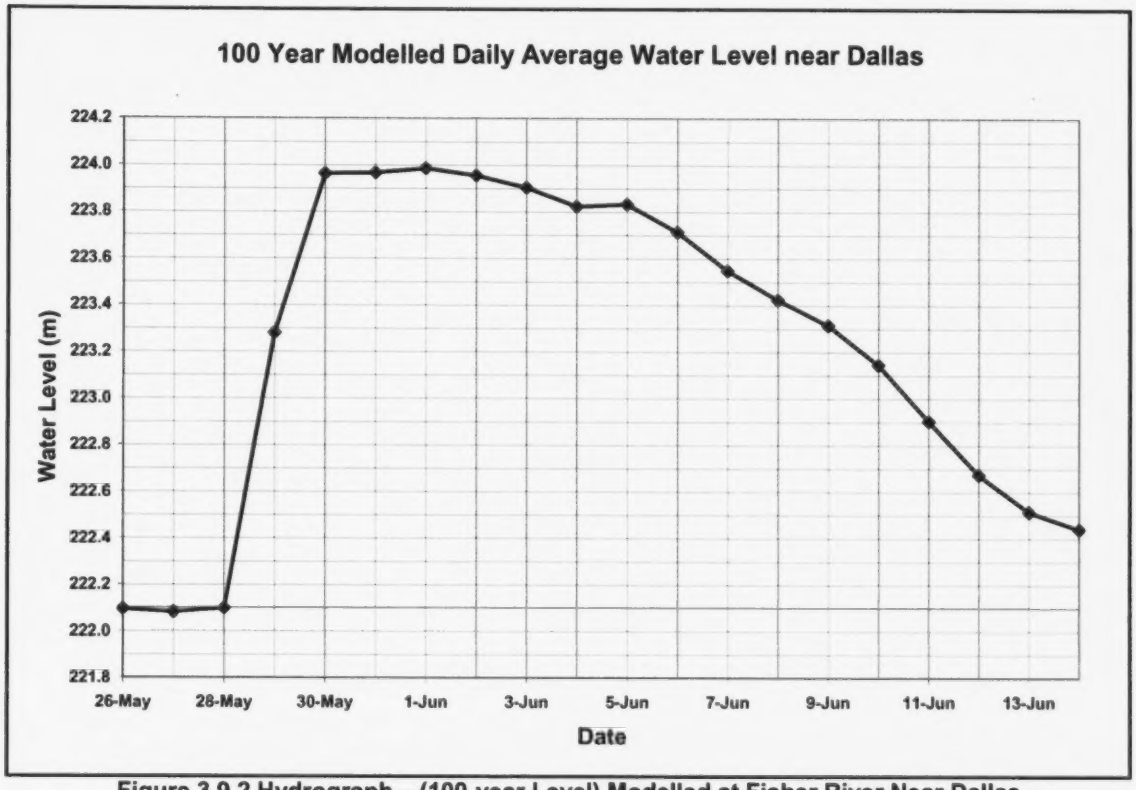


Figure 3.9.2 Hydrograph – (100-year Level) Modelled at Fisher River Near Dallas

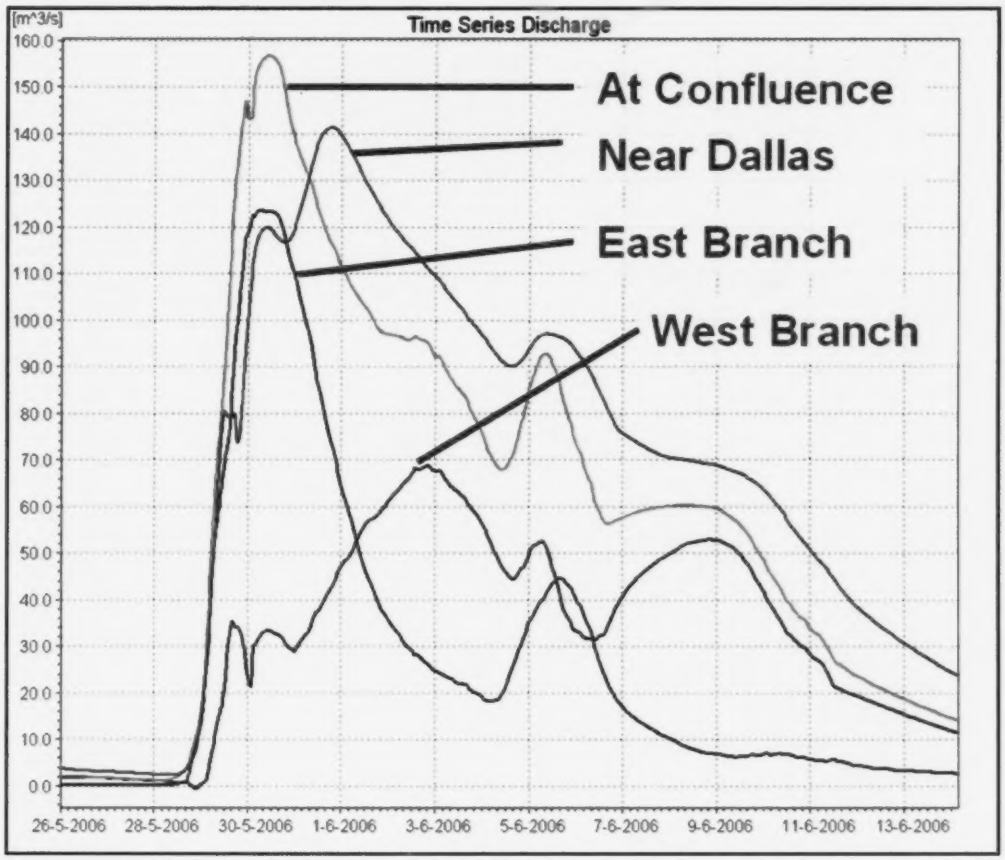


Figure 3.9.3 Hydrograph – (100-year Flow) Various Locations

Figure 3.9.3 compares flows at the gauge with flows at the West Branch and East Branch just upstream of the confluence and in the main stem just downstream of the confluence.

Figure 3.9.4 shows the MIKE11 model hydraulic profile on the Fisher River main stem. The natural riverbed undulations are clearly visible at the base. The minimum flow water level profile is illustrated as a green dashed line near the river bed at rapid sections. Maximum high water levels are also shown as a dashed line in red just above the blue water profile. The water profile is shown at an instant in model time when the flood peak is passing through the Fisher River near Dallas gauge. This gauge is upstream of the Fred Stevenson crossing. The bridge labels indicate the level of the bridge deck or crossing.

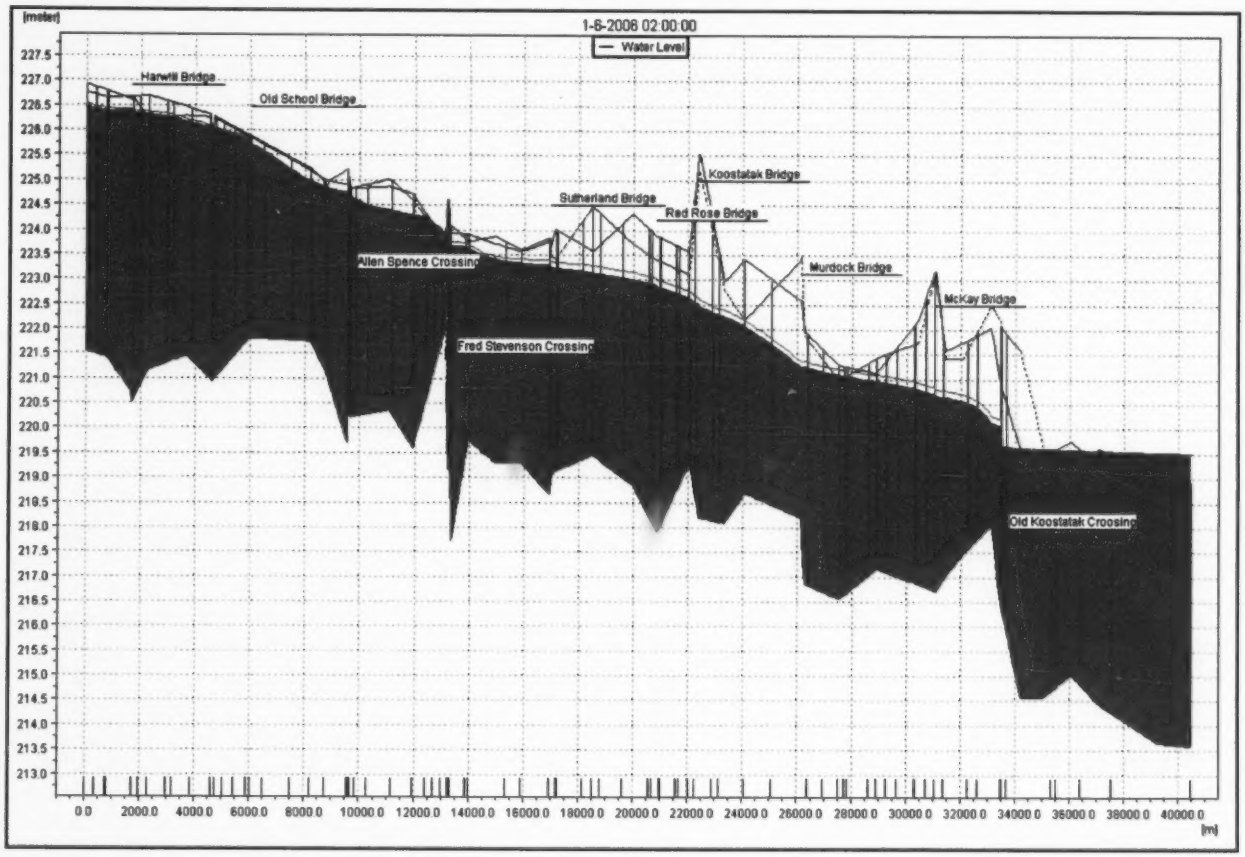


Figure 3.9.4 MIKE11 Profile on Fisher River Main Stem – (100-year Flow)

4. Flood Zone Map

4.1 Flood Zone Mapping

The calibrated MIKE 11 model was run to simulate the flood zone for an event with magnitude similar to the 2006 event and the event with 1% probability of exceedance (100-year Flood). The flood inundation map was based on hydraulic response of the river model to modelled rainfall events. The river elevations were extrapolated onto the floodplain perpendicular to the river channel or floodplain channels. The floodplain was represented by the LiDAR based digital elevation model. A visual comparison was made between the 2006 reported observations of flooding and the modelled flood map.

Based on these modelled conditions, the calibrated MIKE 11 model was run to simulate the flood zone for the 100-year flood event. The existing condition model showed flooding in most reaches downstream of the Fisher River confluence including parts of the Peguis and Fisher River Reserves. Flood inundation maps for the 100-year event were produced to illustrate the extents of flooding for the extreme event under existing conditions and with mitigation options. The flood maps are shown in Appendix A.

Flood inundation mapping and predictive accuracy was discussed with members of the affected communities and the Technical Advisory Committee (TAC).

4.2 Inundation Region for 2006 Flood

Historic flood inundation maps were available for the 1998, 1979 and 2006 flood event. The flood events of 1998 and 2006 were considered to be fair representations of a gauged flow event of 73 m^3/s magnitude. The 1998 flood map had been produced in support of a flood damage claim.

Some uncertainty was expressed regarding the accuracy of flood maps produced for historic events but the simulated flood maps were deemed to be a reasonable representation of the extent of flooding. Figure 4.2.1 shows the extent of the 1998 flood map that had been produced in support of a flood damage claim. One of the things that must be considered is that the 1998 event occurred in the spring and the maximum extent of flooding may have been affected by ice jams in the channel and thus is not directly comparable to the open channel 100-year event except in the general pattern of flooding.

The 1979 flood event as shown on Figure 4.2.2 had a peak flow of 123 m^3/s event which is much closer to the simulated 100-year flow of 135 m^3/s at the gauge. The pattern and extent of flooding is similar on both images.

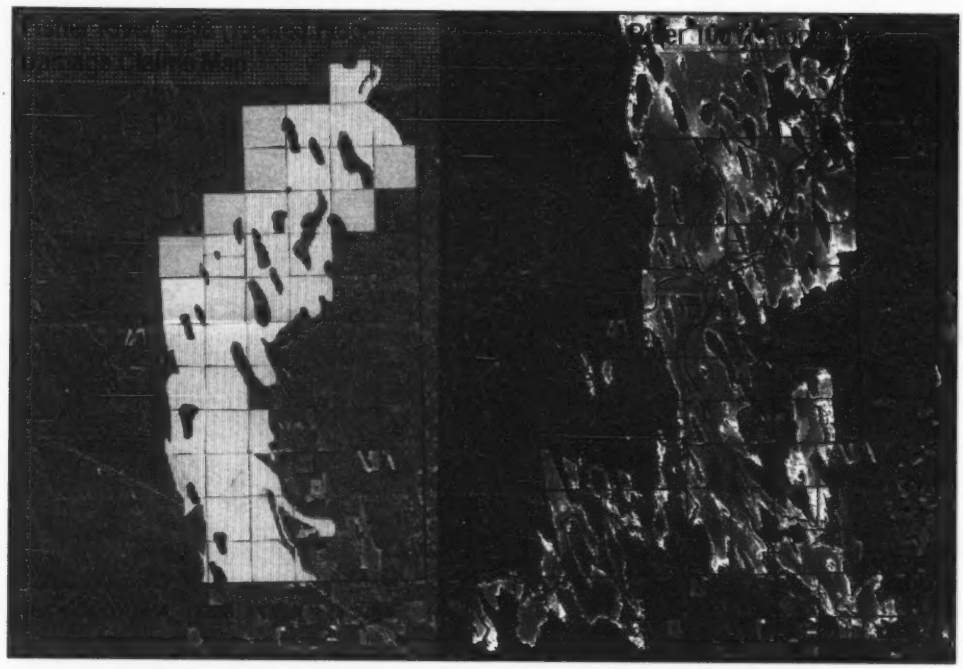


Figure 4.2.1 Flood Map for 1998 compared with 100-year Model Output

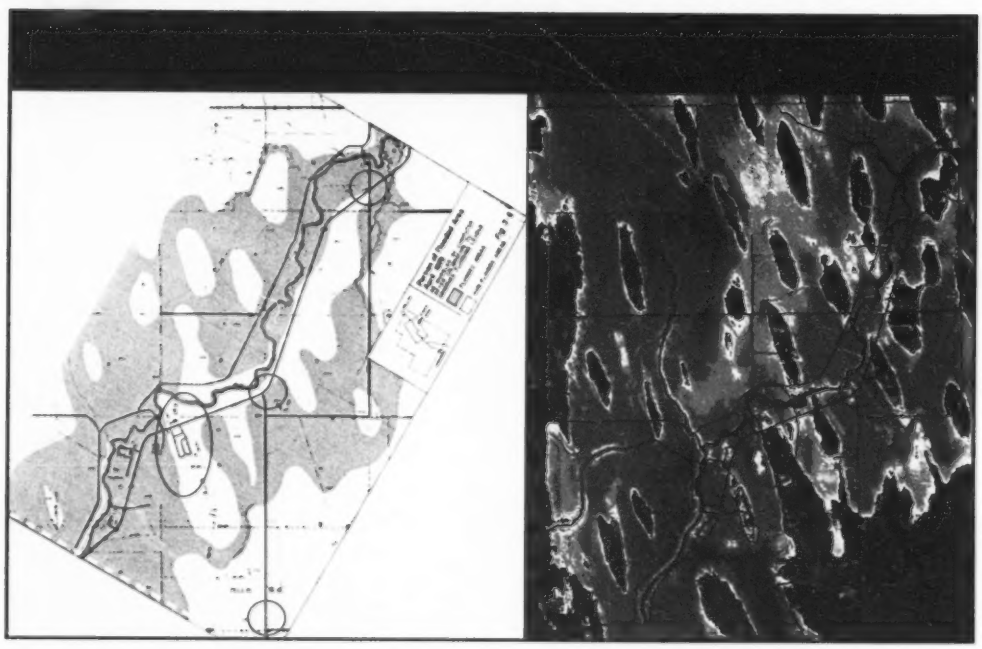


Figure 4.2.2 Flood Map for 1979 compared with 100-year Model Output

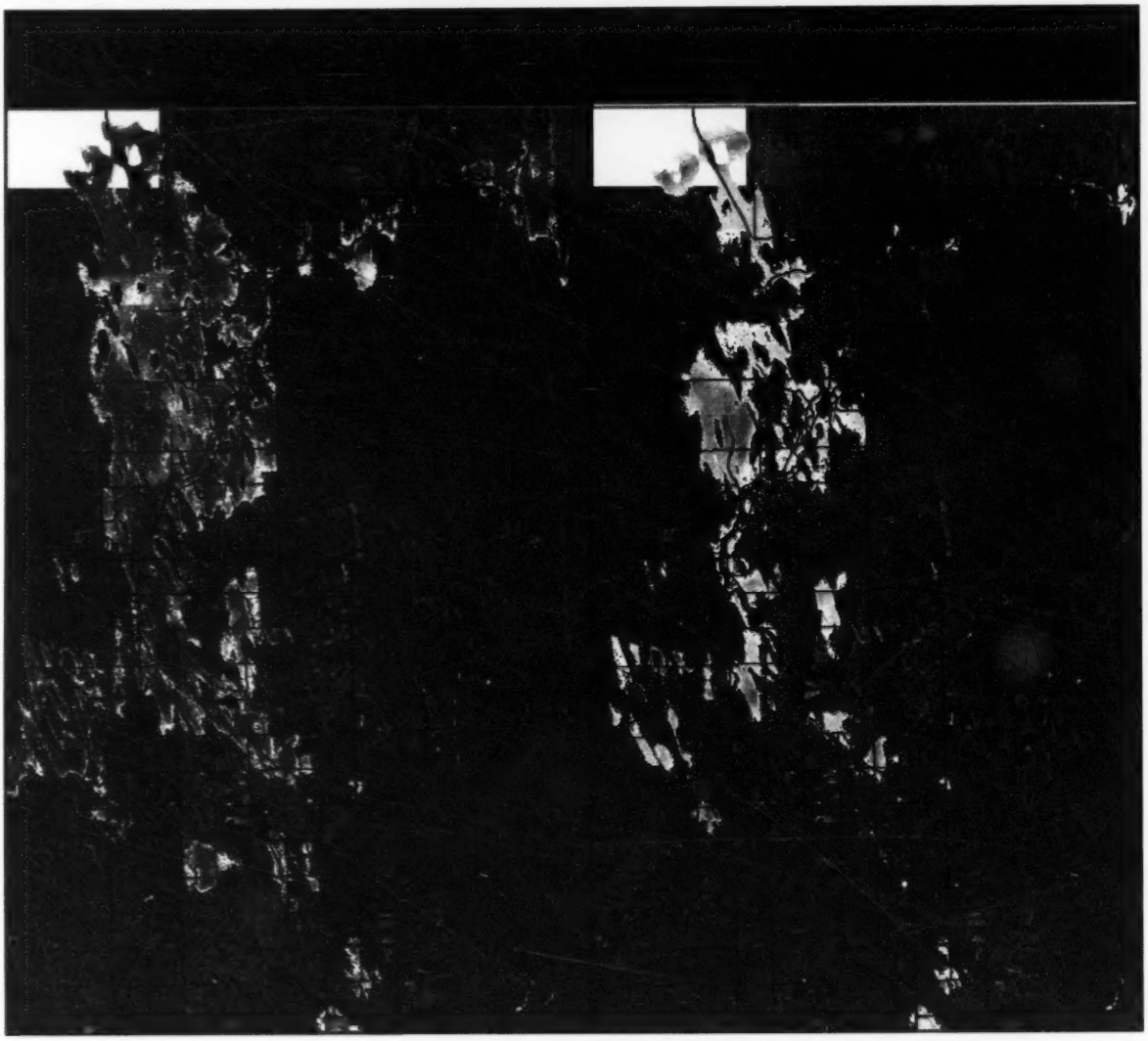


Figure 4.2.3 Flood Map for 2006 Compared with 100-year Model Output

4.3 Flood Zone for 1% (100-year) Flood

The MIKE11 Model was run in the simulated 100-year rainfall event conditions to predict the flood zone response to the 100-year flood under existing conditions. Figure 4.3.1 shows the flood zone resulting from the 1% or 100-year event.

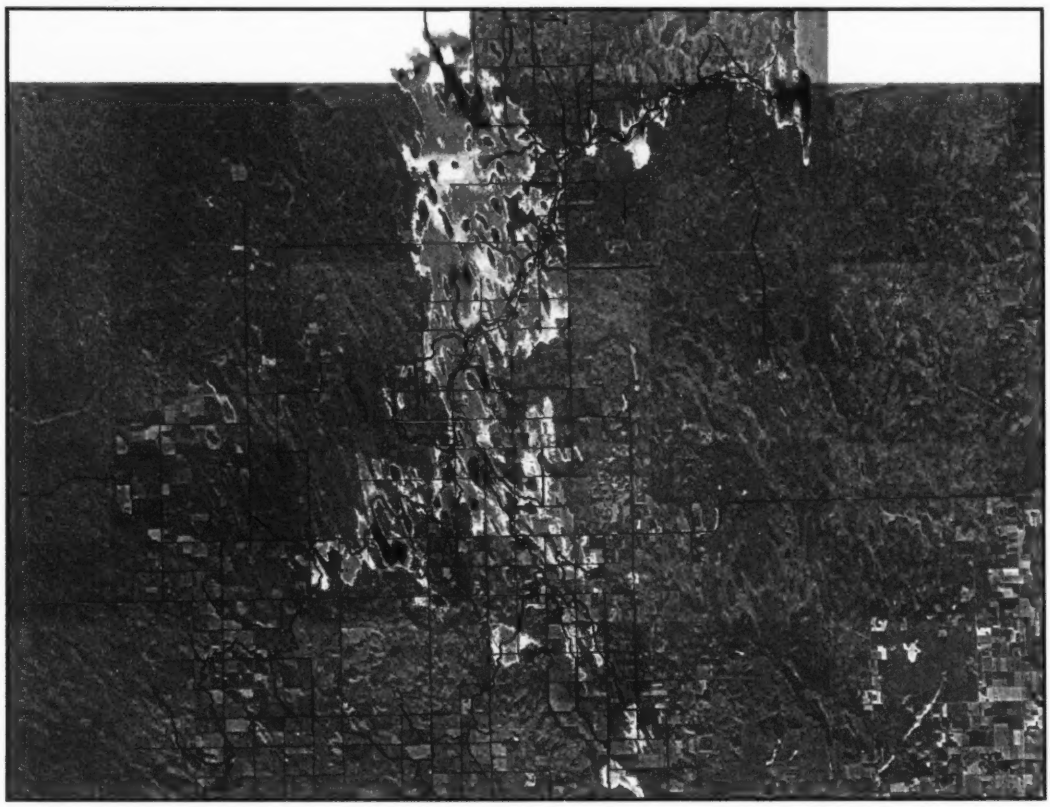


Figure 4.3.1 Modelled Flood Inundation Map for 1% event

It should be noted that some variation is found between the modelled flood inundation maps in comparison to previous flood maps. This difference may be attributed in part to the uncertainty of previous maps and the definition of flooding applied when producing those maps. Previous maps may have included lands too wet to generate crops, which may have included influences from ground water saturation and high water table resulting after a period of surface flooding. Flood zone variations may also result from conditions created as a result of temporary ice jams. Ice-related flooding was not included in the MIKE11 model and was not reflected in flood zone mapping.

A series of flood maps was prepared showing the 100 year flooded area between the south boundary of the Peguis First Nation and Lake Winnipeg. These images are included as Appendix A and the flood zones are available as GIS polygon SHP files.

The MIKE 11 model was also used to simulate the 100-year flood for modified river conditions representing various mitigation options. These conditions are described in Section 5 below.

4.4 Ice Jam Influence on Flood Magnitude

The MIKE11 model shows the 100-year flood zone with existing river configuration and open water conditions. However, additional flooding or increase in water surface elevation should be anticipated at any location based on the probability of ice jamming at a bridge or natural constriction in bed or bank along the river. Although it is difficult to predict the local impact or duration of such events, local flood levels could be affected in the order of 1 meter and some additional safety margins should be applied to model-predicted levels to account for such uncertainty.

Ice-jam affected flood levels were not predictable and could not be modelled accurately. The influence of local ice jams may help to explain some of the variation seen in historic claims and flood records with flood zone maps defined by others.

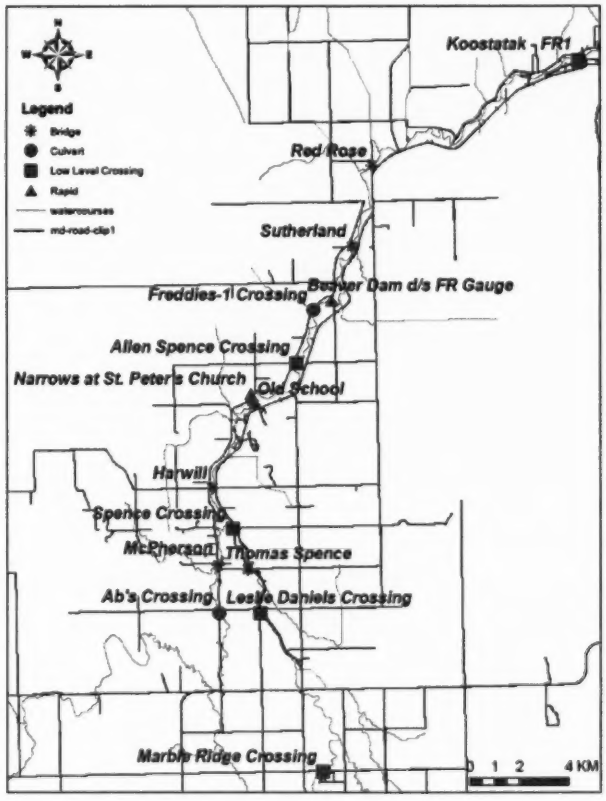


Figure 4.4.1 Ice Jam Location and Causes – *Anecdotal Data*

5. Flood Mitigation Models

5.1 Historic Mitigation Options

Previous consulting reports on Fisher River Basin flooding were considered during this study. These reports were based on significantly varied levels of effort. Some reports were based on cursory review of the basin flooding situation and speculation based on generally accepted engineering principles. Additional speculation was presented on hydraulic feasibility and cost effectiveness of various mitigation options. Other reports included some level of modelling effort and presented mitigation strategies considered effective at the time. These reports appear to have influenced the appeal of various mitigation options. Modern land settlement patterns and improved understanding of regional geography have changed the feasibility of some of the mitigation options which were presented in past reports.

Historic mitigation options considered flood proofing existing properties at risk, detention at various conditions and flood flow diversion. Flood proofing was comprised of combining community ring dykes around residential clusters, raising individual homes on existing lots, and total relocation of most severely affected homes. Flood zones were defined to encourage development and risk reduced construction to less flood-prone regions.

Community settlement along the river has ruled out the detention options presented in the early 1980's. The detention options presented in the Hydrotek Report (July, 1082) was proposed at the location of the existing Peguis community.

Improved geographic tools and hydrologic and hydraulic modelling tools are now available to scientifically estimate the relative suitability of various mitigation options. Flood proofing individual homes and community ring dykes along with containment by dykes built parallel to the river were also considered. Diversion routes presented in the historic reports and other routes suggested by the community were considered and preliminary estimates generated for channel dimensions, excavation volume and cost of various diversion routes.

5.2 Current Mitigation Options

In order to identify the effectiveness of various Technical Advisory Committee (TAC)-selected flood mitigation alternatives, the 100-year flood was modelled with six different flood mitigations. These mitigation options include modification of the river channel, dyking, diversion and storage:

Option 1 – Low Level Crossing Replacement with Box-Culvert Crossings

Option 2 – Option 1 plus Channel clean-out

Option 3 – Option 2 plus Removal of selected rapids,

Option 4 – Raising Containment Dykes,

Option 5 – Diversion to Lake Winnipeg

Option 6 – Upper Basin storage.

Fisher River flooding has been reported with flows of 60 m^3/s or approximately 50% of 1979 observed peak. Present flow analysis indicates 81 m^3/s occurs on a frequency of approximately 1 year in 7.5 Years (13.3% event). The 100-year flood magnitude was estimated as 138 m^3/s at the gauge Fisher River near Dallas. Given the stream hydraulics and locations of available floodplain storage, a peak flow at the confluence of the West and East Branches is greater than the corresponding flow measured at the Dallas gauge. Inflow that resulted in a flow of approximately 138 m^3/s at the Dallas gauge was used to compare mitigation options.

Hydraulic impact or effectiveness of the mitigation options are presented in following sections.

5.2.1 Low-Level Crossing Replacement with Box Culverts

Discussion with residents in the Fisher River basin quickly indicated the importance of the existing access across the river. Residential settlement has occurred on both sides of the river. Most of the community services in Peguis First Nation are located on the east bank, while in Fisher River Cree Nation most community services are located on the north bank requiring frequent crossings by area residents. In addition to the 18 bridges north of PR 325, there are five low level crossings with culverts.

Low level crossings (or "ford crossings") have a road top profile below the river bank (thus "low-level"). They provide stream crossing access under low flow conditions but are frequently submerged for short periods by small magnitude storm peaks. Larger events block the passage for longer periods and cause more extensive damage to the low-level crossing. Culverts may not be appropriately sized to convey storm flows at these crossings, rather readily available culverts are installed with shallow cover of rock fill and granular materials to save cost. Temporary service losses are experienced frequently due to road wash-outs caused by over-topping weir flow removing granular driving surfaces and destructive removal of the culvert in extreme flow cases. Examples of low level crossings with downstream granular material deposition are shown in Figures 5.2.1 and 5.2.2.

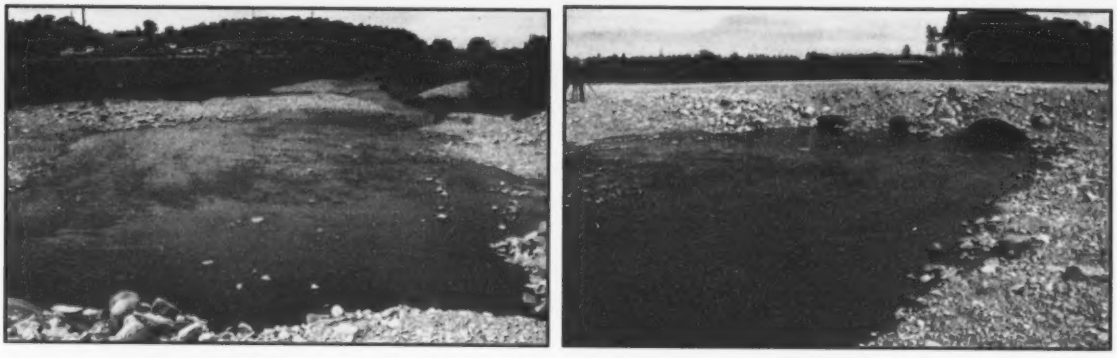


Figure 5.2.1 Low-Level Crossing at Les Daniels Auto Repair (downstream end)

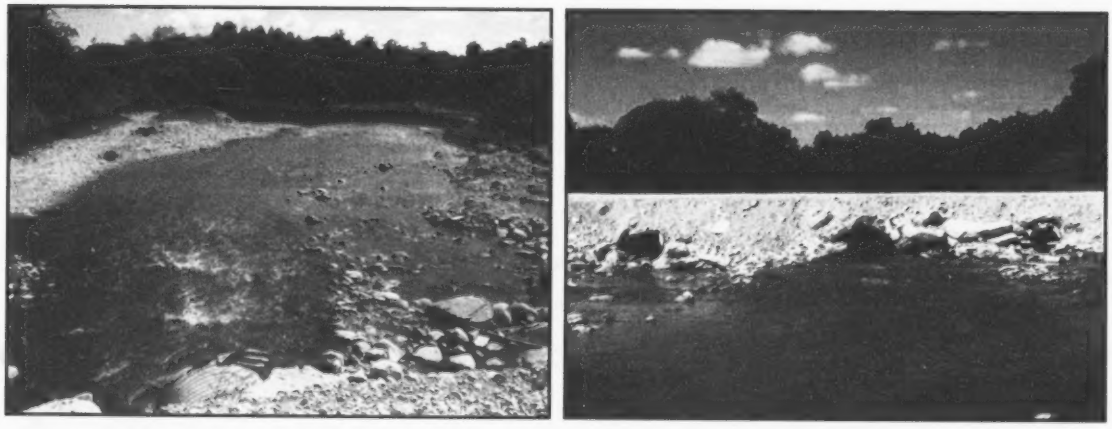


Figure 5.2.2 Low-Level Crossing at Fred Stevenson (downstream end)

Hydraulically these crossings frequently act as weirs obstructing low-flow stream conditions. The limited capacity of the culverts cause water levels to rise upstream of the crossing even under small magnitude floods. Large elevation differences (high head) across the low-level crossing cause increases in localized flood levels. Large water level differentials also motivate high velocity flows through the culvert and eventually overtop the road crest. The frequent erosion of granular material causes material to build up in the downstream river bed and further reduces the hydraulic capacity of the river.

The first mitigation option considered was to replace the low-level crossing culverts with more permanent and hydraulically efficient box-culverts. A conceptual design was configured with four parallel box culverts each of 2.44 m rise by 3.05 m span. The culverts would be designed with suitable foundation to prevent downstream displacement and fixed together laterally to act as one unit with a shallow layer of

cast-in-place reinforced concrete providing a permanent driving surface. Guard rails would be designed to provide safety to vehicular and pedestrian traffic with the ability to be temporarily removed in advance of predicted high flow events with potential for ice movement.

Upstream ends of the culvert system would be bevelled to improve hydraulic efficiency and to present a gradually rising front allowing mobile ice sheets to ride over the structure instead of flipping up to create a plate-like obstruction to flow. Bevelled leading edge treatment would be protected with steel angles for strength and to assist break-up of advancing ice sheets.

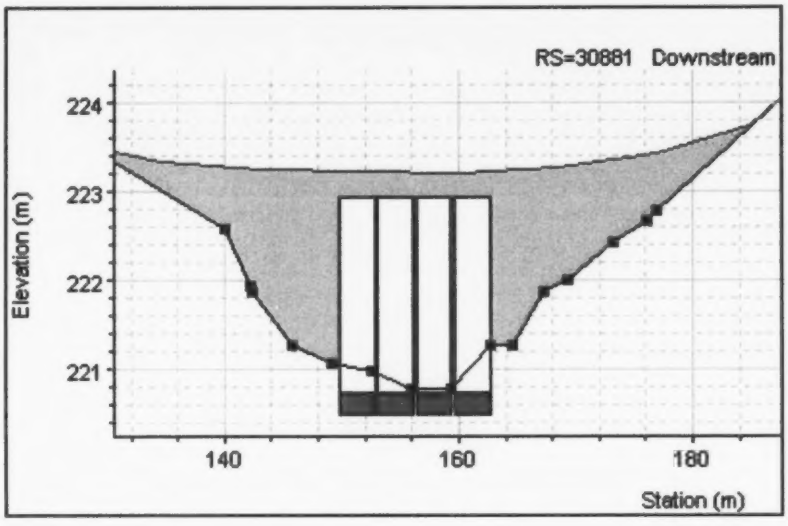


Figure 5.2.3 Conceptual Low-Level Crossing with Box-Culverts (Allen Spence Crossing)

Crossings with replacement box culverts were analysed with flows in the order of 30 cms which is less than the 2-year design flow of 36.4 cms. The advantage of concrete box culverts would be the durability and increased probability to withstand large flow events without loss of structural integrity or washout of driving surface. This would provide the advantage of earlier service restoration and prevent hydraulic and habitat deterioration in the downstream river bed. Adequate armouring of approach road embankments would also be required to prevent washout during high flow events.

Box-culvert crossings were modelled at four locations: Leslie Daniels, Fred Stevenson (Downstream of the Fisher River gauge near Dallas); Allen Spence (or Pine Cone Road); and at Ab McPherson's culvert (presently a large diameter culvert, not a low-level crossing). Box-culvert replacement locations are shown in Figure 5.2.4 as stars along with other bridge and crossing locations. The last existing low-level crossing at the old Koostatak Bridge location (PFRA Cross-section FR-1) was modelled with a single pier, twin-span bridge copied from the McKay Bridge (in the order of 20-30m span). At present this location has a temporary low-level crossing with three culverts. At the time of mitigation modelling this crossing

was being considered as a site for bridge replacement. However, it may be well suited for replacement with a box culvert system designed to suit the site.

The modelled hydraulic profile in Figure 5.2.3.1 shows Fisher River under existing conditions compared with low-level crossings replaced with box culverts at four locations plus the new bridge at Old Koostatak. Some head loss is evident across the box culvert structures, but this head loss is less than what was evident under present conditions. The modelled[6] four-box culvert system has head loss of 0.15 m at 32 m^3/s, 0.04 m at 63.2 m^3/s, 0.01 m at 145 m^3/s.

Figure 5.2.4 Low-Level Crossing Replacement Locations

[6] Modelled at UMA in HEC-RAS 3.1.3

This mitigation concept provides very small local improvement of flooding upstream of present low-level crossings for the 100-year event. The local benefit is limited to a distance of less than one kilometre. At Ab McPherson's crossing, where the local water level reduction is a maximum of 1 m at the crossing, the reduction is less than 0.3 m by a distance of 4 km. The benefit of low-level crossing replacement is greatest for low flow events and is less noticeable under extreme events. Minor increases in downstream flooding are noted due to the improved hydraulic efficiency of the upstream river crossing.

The major benefit of low level crossing upgrades with box culverts is realized in terms of earlier restoration of traffic service following flood events and environmental protection issues.

Department of Fisheries and Oceans (DFO) concerns have been considered in the box-culvert replacement mitigation concept. Flow velocities within the culvert structure and downstream of the culvert are reduced to within acceptable limits due to lower head differentials, thus improving the success of fish passage. Further fishery benefit is realized in reduced habitat lost through granular debris deposition downstream of low-level crossing washouts.

5.2.2 Channel Clean-Out or Bed Restoration

The second option to mitigate Fisher River flooding was to combine channel clean-out with the previously described low level crossing replacement by box-culvert systems. Frequent washouts of low-level crossings and subsequent accretion of granular materials downstream have accumulated a significant obstruction to hydraulic capacity of the Fisher River.

The MIKE11 model was run with the 100-year flow in the existing condition and compared to a condition where three low-level crossings downstream of Hodgson were modelled to simulate bed slope restoration. Figure 5.2.2.1 shows the existing river bed profile and hydraulic grade line (HGL) with bed trimming in combination with Option 1 low-level crossings replaced with box culverts as shown above.

Restored open-channel conditions were modelled by straightening (often lowering) the bed profile between upstream and downstream cross-sections selected to represent the nominal bed profile beyond the reach with debris deposition. An example of grade restoration is shown in Figure 5.2.2.1.

Under the model conditions for combined Mitigation Options 1 and 2 the maximum water levels at Ab McPherson crossing were further reduced 0.1 m for the 2006 flows and 0.3 m for the 100-year flows. Other locations had results similar to the Option 1 conditions.

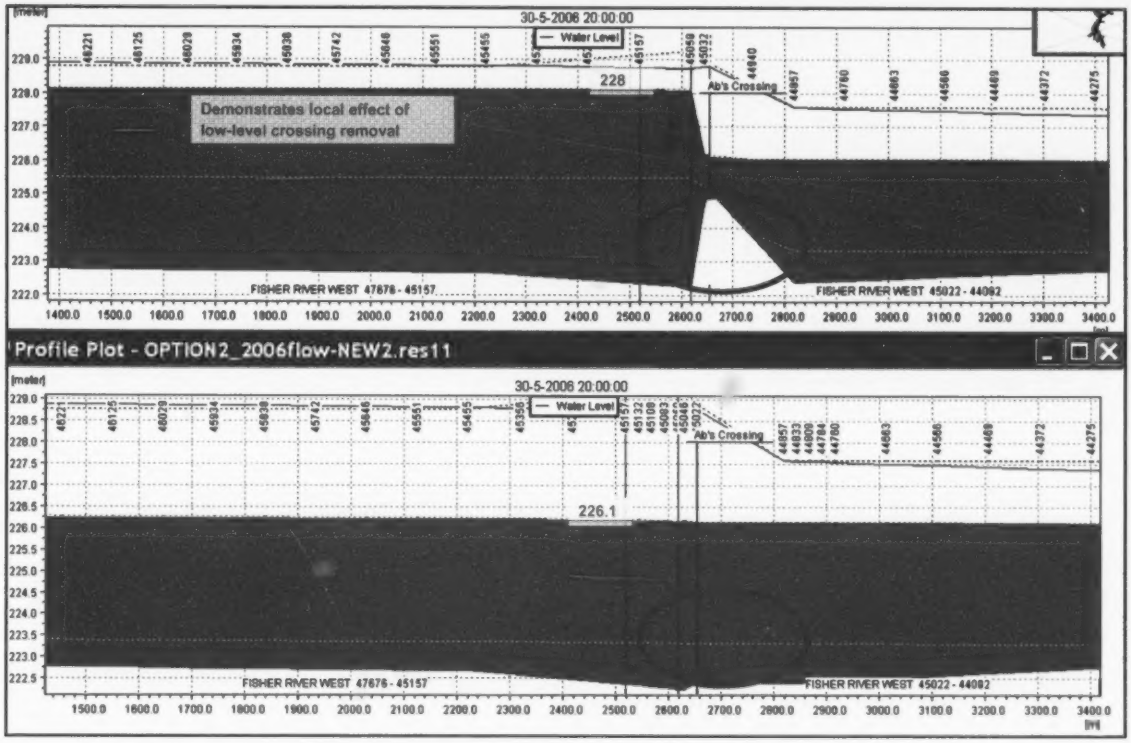


Figure 5.2.2.1 Fisher River Existing Bed Profile Restoration

Table 5.2.2.1 Water Level Change from Existing Condition - Ab McPherson's Crossing

Flow Event	Option 1	Option 2
2006	-1.82 m	-1.91 m
100-year	-0.74 m	-1.06 m

The channel restoration concept may potentially raise fishery habitat issues. However, it is reasonable to present this concept as an overall benefit to the fishery by drawing attention to the reduced numbers of catastrophic failures of the road embankments, culvert washouts and associated bed aggradation. Further habitat improvements could be considered in the detailed design phase by recreating riffle and pool structures to provide additional habitat suitable to local fish species. Such channel bed restoration could be designed to restore fishing habitat and accommodate fishing in these traditional areas.

5.2.3 Rapids Removal

As in the case of bed restoration, hydraulic efficiency can be gained in the Fisher River by removal of selected natural rapids. Historic reports (Kuiper, '79 & Hydrotek, '83) suggested removal of selected rapids to a depth in the order of 2 feet (0.6 m) to consider the net benefit to flooding situations. Those studies estimated local hydraulic benefits to a maximum of one foot at Fred Stevenson Rapids. Other locations were estimated to have less benefit with maximums in the order of a ½ foot where floods already inundated river lots to a depth of 4 feet, realizing little net benefit to homes existing in the floodplain. The present study simulated removal of two rapids to restore nominal bed slope.

Mitigation Option 3 is the combination of Options 1 & 2 described above plus rapids removal at #6 and #12 (based on the numbering scheme proposed in the 1983 Hydrotek report). Rapids #6 is located at Fred Stevenson (downstream of the Fisher River near Dallas Gauge) and rapids #12 is located upstream of the old Koostatak Bridge location as the last rapids before discharging into Lake Winnipeg.

The model simulated rapids removal by transposing an unobstructed upstream cross-section to the stations of the rapids cross-sections. This lowered the Fred Stevenson bed profile 2.2 m and lowered the bed profile 1.5m at the Old Koostatak crossing. Bed profile changes were conceptualized as occurring over a distance of 1250m at Fred Stevenson crossing and 2370m at the Old Koostatak crossing. Volume of excavation was in the order of 92,590m^3 at Fred Stevenson and of 190,290m^3 at Old Koostatak crossing. Local flooding is predicted to be 0.47m lower than exiting condition water levels at the Old Koostatak crossing.

Figure 5.2.3.1 shows the water surface profile with existing natural bed conditions and the improved hydraulic grade line with rapids removed in combination with Options 1 & 2 above.

Similar to bed clean-out, rapids removal may raise habitat issues with the fishery department. Again habitat improvements could be considered in the detailed design phase by providing habitat suitable to local fish species in this or another reach of the river.

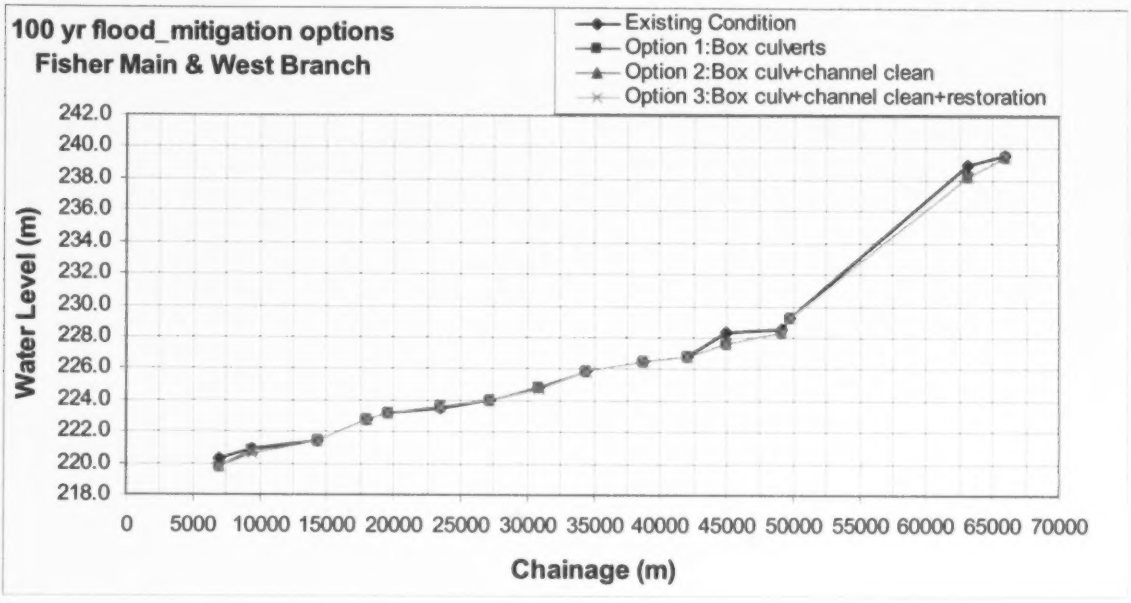


Figure 5.2.3.1 Fisher River & West Branch Profile –Existing Condition & Mitigation Options 1, 2 & 3

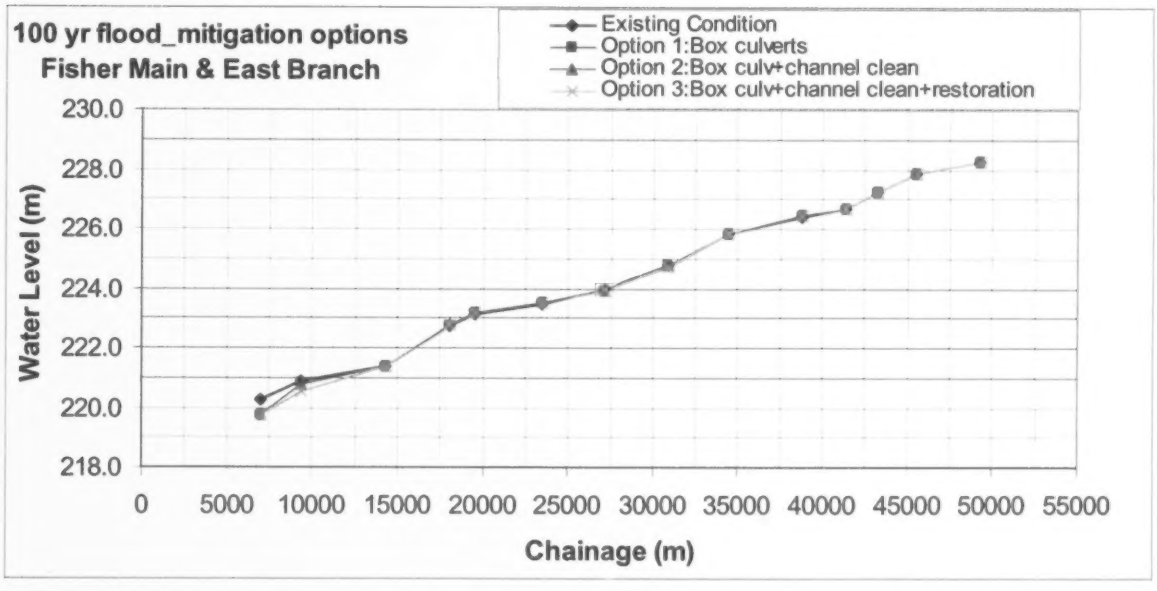


Figure 5.2.3.2 Fisher River & East Branch Profile –Existing Condition & Mitigation Options 1, 2& 3

5.2.4 Flood Containment Through Parallel Dyking

Natural floodplains serve to reduce the height of floods by increasing the conveyance area and storing water in depression area to be released back into the river at a later time thereby prolonging the duration of the flood. Removal of the floodplain forces all the flood flow to be conveyed in a width reduced cross-section area forcing the water depth to rise in order to convey the same flow rate. Further demand is placed on the river channel by reduction of storage potential in the floodplain. Dyke-constrained floods are subsequently higher but the duration is shorter.

The Fisher River channel north of PR 325 has roads constructed on both sides of the river. In places west of Peguis and north of the Harwill Bridge the parallel roads are within 170 m of each other and act as low dykes on each bank. In some locations access roads or driveways may impinge on the river flow further.

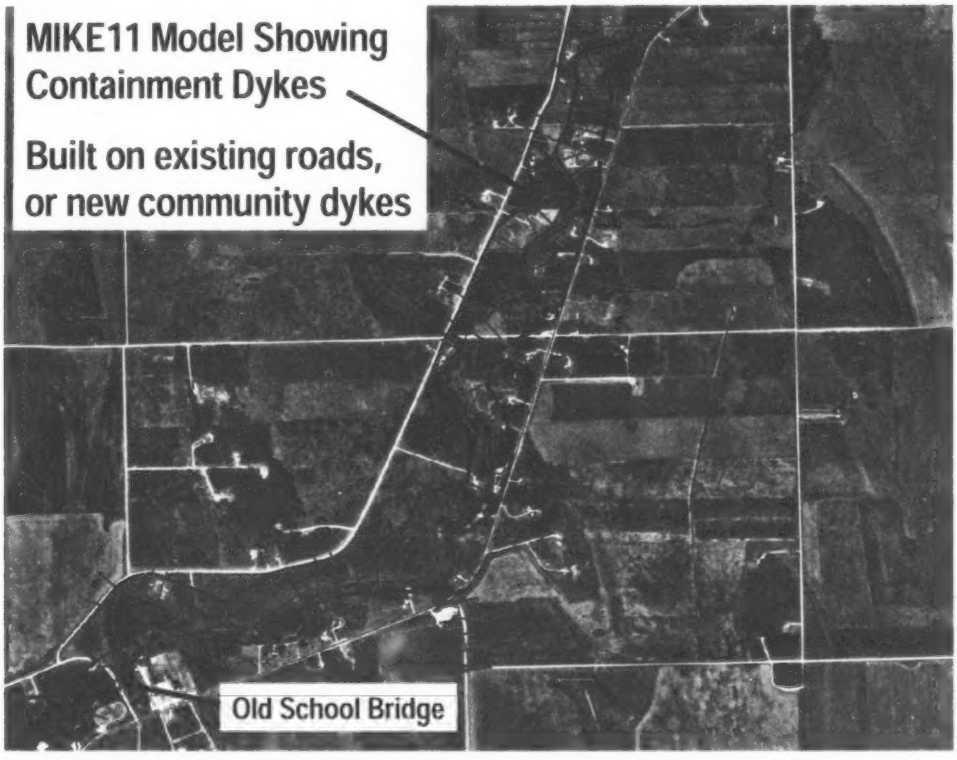


Figure 5.2.4.1 Plan Showing Parallel Dykes Near the River Channel

In the existing condition, drainage from areas beyond the roads is conveyed by ditches flowing toward the river and passes through gated culverts penetrating the parallel roads. In the dyked condition, after the river flows are constrained within the river channel between the parallel roads and are prevented from overflowing to the natural floodplain by these roads and gated culverts.

Raising the roads has been considered in the past as has construction of parallel dykes with smaller section area for reduced construction volume. An early concept of parallel dykes is shown in Figure 5.2.4.2.

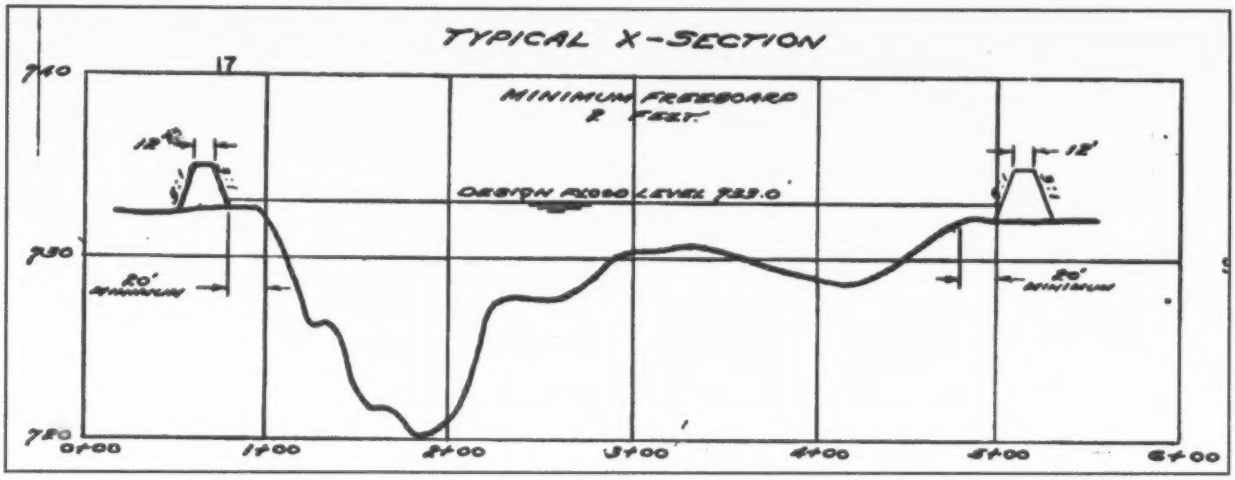


Figure 5.2.4.2 River Cross-Section Showing Containment Dyke Concept (PFRA)

Mitigation Option 4 considered the hydraulic impact of raising dykes to heights as required to contain all flood peaks within the channel. In the hydraulic model some dykes were raised adjacent to existing roads and dykes, others were placed on banks where no previous dyke had been built. These new dyke locations were located at the limit of available river cross-section information. In locations where residential clusters exist on river banks, community ring dykes were conceptualized to protect these groups of homes. The first dyke alignment veered to protect some house clusters. Other residential assets were not available until after mitigation modelling. Further optimization of dyke alignment would increase the economic and social benefit to the community with small changes to dyke construction costs.

Table 5.2.4.1 Containment Dyke Classified by Height

Dyke height<1m		Dyke height >1m, <2m		Dyke height t>2m, <3m		Dyke height> 3m, <4m	
L	R	L	R	L	R	L	R
27%	25%	17%	20%	33%	37%	24%	17%
26%		19%		35%		20%	

Flood peaks within the dyke-confined river channel would be higher than in the existing condition. The advantage of mitigation option 4 is that the aerial extent of the flood inundation zone would be reduced.

Some culverts lateral to the river channel were considered to be flap-gated to prevent flow reversal from the confined river channel to the floodplain. In periods of high river stages, gravity drainage from lateral areas would be prevented from entering the river due to closed backflow prevention gates. High river stages would close the flap gates and temporarily force runoff into storage in ditches and on fields. The MIKE11 model simulated this condition by removing all lateral culverts. Tributary streams were still able to contribute flows to the dyke-constricted channel as a function of dynamic state water levels in the main stem and tributaries.

Mitigation Option 4 results showed that for the 2006 runoff event there was a 0.2 m to 0.4 m rise in main stem water levels within the river-containing dykes. For the 100-year event the model predicted water level increases in the order of 1.0 m to 2.0 m between the dykes.

West and East branch reaches predicted small increases (0.16 and 0.15m respectively) in water levels near the confluence. The 100-year flood predicted water level increased to 1.0m above existing conditions at the confluence with level increases diminishing in the east and west branches with increased distance upstream

5.2.5 Flow Diversion

Diversion to Lake Winnipeg was the Mitigation Option 5 strongly favoured by the First Nation Communities. This may be due to the perception formed from past studies. With improved topographic information more thorough consideration was given to the hydraulics of conveying these flows to a natural outlet downstream of the current population.

Initial analysis indicated a diversion would require a hydraulic capacity in the order of 50 m^3/s or greater. A diversion outlet capacity of 150 m^3/s was required to reduce existing peak flow to the 60 m^3/s in-channel limit.

The Fisher River flows naturally in a north to north east direction so a shortened path could be achieved by diverting to the north east through bog regions. A diversion concept flowing directly east along the PR 325 alignment was presented by the TAC. This route was analyzed visually on topographic and geology maps and considered infeasible due to complications of carving a diversion channel through a region of shallow rock outcrop with elevations rising in the order of 25 metres above the river bank. Perched lakes and bogs are present in the vicinity of this proposed alignment further complicating the environmental impacts of this alignment. Given the size of the channel at this reach and the resultant excavation volume this route was considered infeasible and further analysis was abandoned. Figure 5.2.5.1 shows an early assessment of the proposed diversion running directly east along PR325. Figure 5.2.5.1 shows an early assessment of a diversion route running directly east along PR 325.

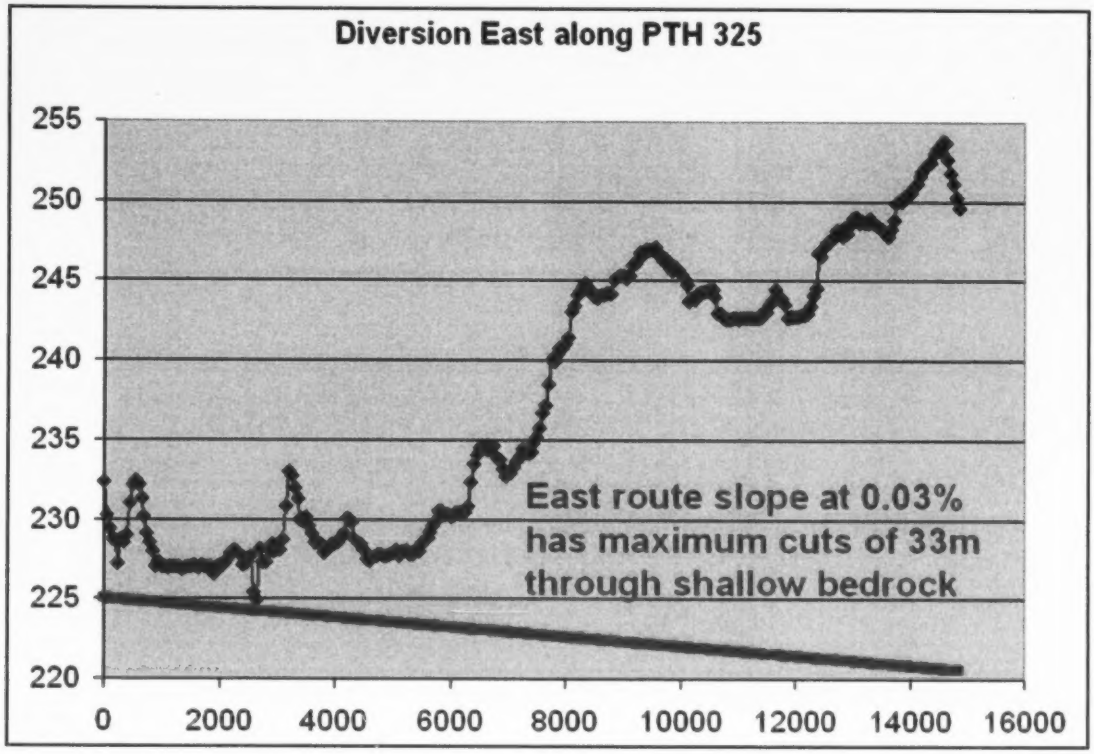


Figure 5.2.5.1 Depths of Cut along PR325 Diversion Route

The Trident report of 1983 (and Hydrotek, 1982) described a diversion channel connecting the west branch of the Fisher River to the east branch approximately 1 km north of the PR325 and flowing east and north to Lake Winnipeg. Dykes across the east and west branch channel with penetrating culverts were conceptualized to throttle flows to such rates (2 outlets of 1500 cfs each[8], or 85 m^3/s) as could be handled by the natural channel through the First Nations lands. The diversion would convey the remainder (7000 cfs[9] or 200 m^3/s) in a wide channel through a series of marsh lands, some of which required dyke containment to prevent breach and re-entry to the Fisher River upstream of Dallas. The diversion route discharged into a tributary of the Fisher River near its downstream outlet into Lake Winnipeg. Figure 5.2.5.2 illustrates the Trident report diversion alignment.

[9] Ibid, p. 46.
[8] Trident, July 1983, p. 46.

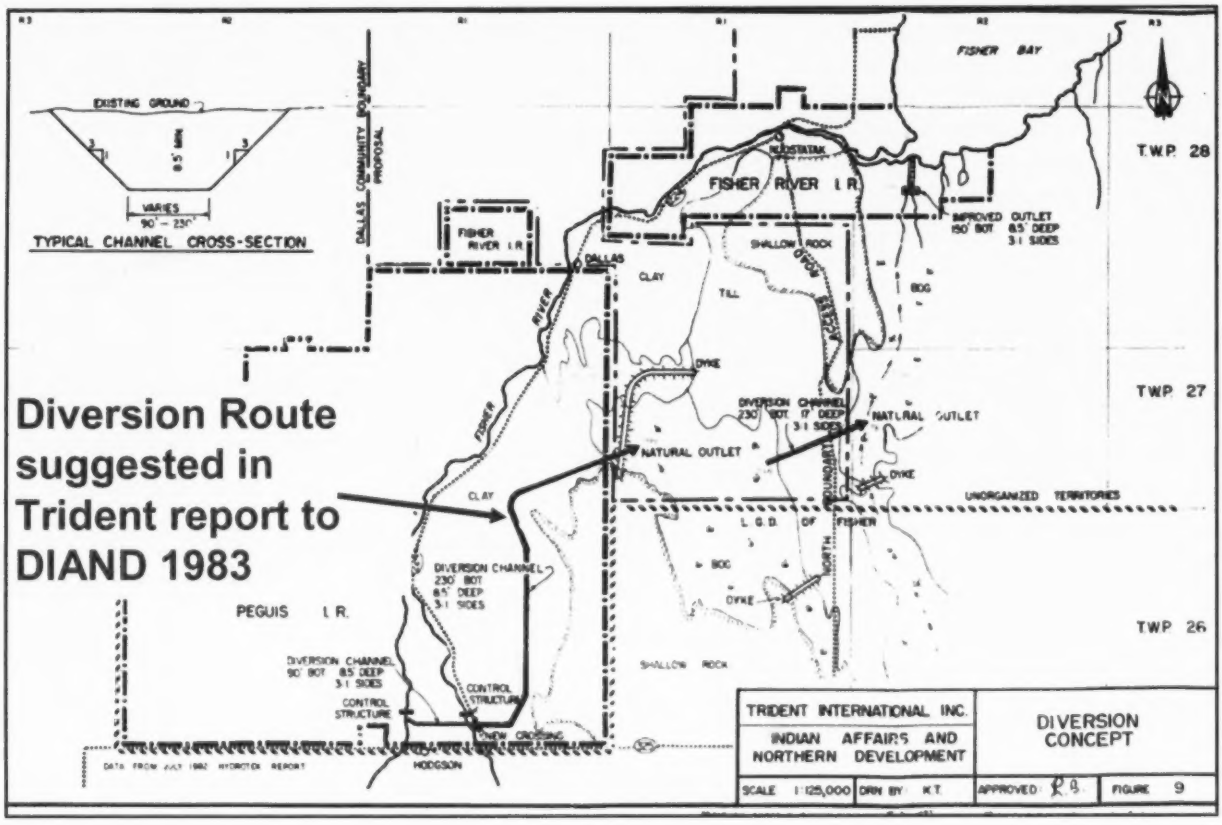


Figure 5.2.5.2 Trident Report Conceptual Diversion Route

The diversion route considered by AECOM followed a similar path as described above but would take into account the improved topographic information that is available. The total length of the diversion is approximately 35km. The West and East branches of the Fisher River would be connected by a diversion channel. The diversion to Lake Winnipeg would begin 72 m wide and gradually reduce to a 30 m width. No restricting dyke across the Fisher River channels was considered in the present model. Channel flow restricting weirs were considered in the Trident concept to throttle downstream flows and elevate water levels in the Fisher River branches and diversion channel.

The diversion channel bottom or sill at the west branch would be set at 225.4 m or 2.3 m higher than the west branch channel invert. The diversion would flow eastward at a slope of 0.07% to intercept the east branch at the east branch invert 223.3 m. The diversion channel invert east of the east branch has a matched invert (223.3 m) and a weir 1.5 m above the channel bed prevents low east branch flows from entering the diversion channel.

The downstream diversion channel invert would range in depth from 4 to 11 m below prairie, with built-up lateral dykes primarily in the downstream reaches to contain the peak diversion flows. The diversion channel concept used 3:1 side slopes in the MIKE11 model. Side-slopes at 4:1 would operate with similar hydraulic capacity, would have better long-term life due nature of local materials and would facilitate maintenance of vegetated side slopes. Side-slopes at 4:1 were used to estimate quantities and and price estimates.

The diversion path as shown in Figure 5.2.5.3 flows directly east 5.6 km (3 ½ miles) before turning north for 11 km (7 miles). At this point the diversion must cross or skirt a natural ridge before entering the first of two bogs. The diversion channel through the bogs would be contained within built-up dykes. Nominal slopes of 0.02% would produce velocities in the range of 0.7 to 1.3 m/s with extreme velocity of 2.77 m/s for a short stretch of the downstream reach. If diversion was selected, further hydraulic optimization could improve this local velocity condition.

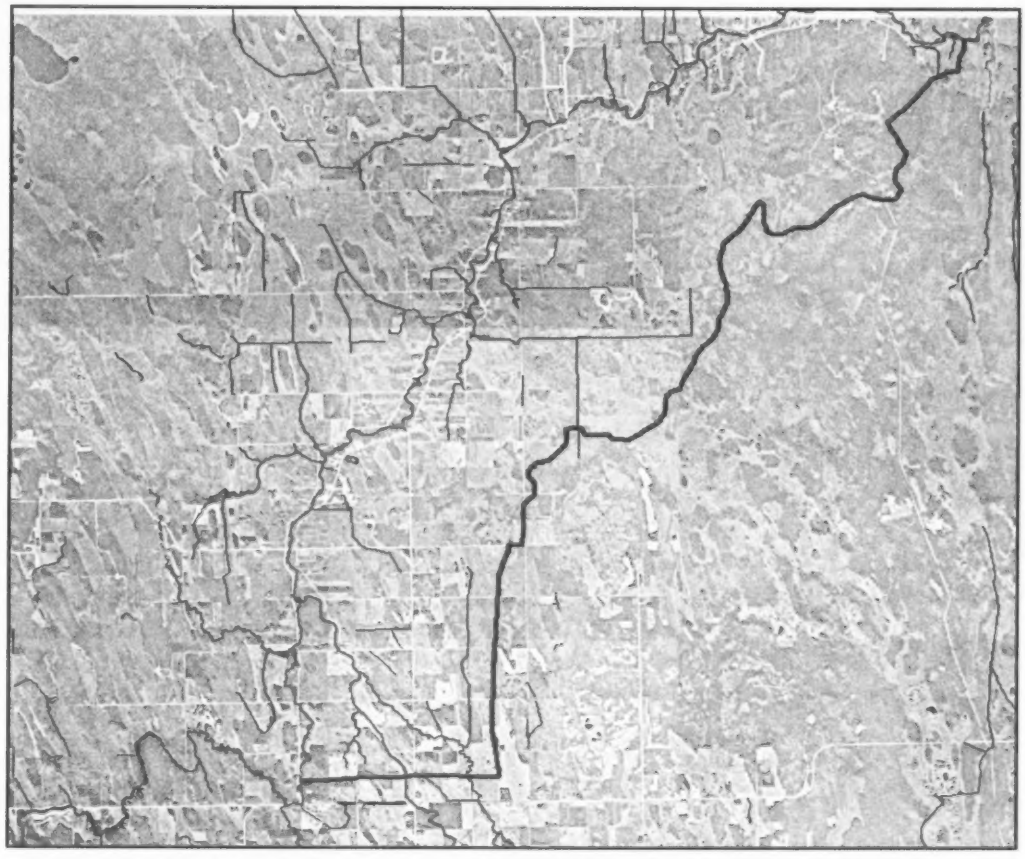


Figure 5.2.5.3 AECOM Conceptual Diversion Route

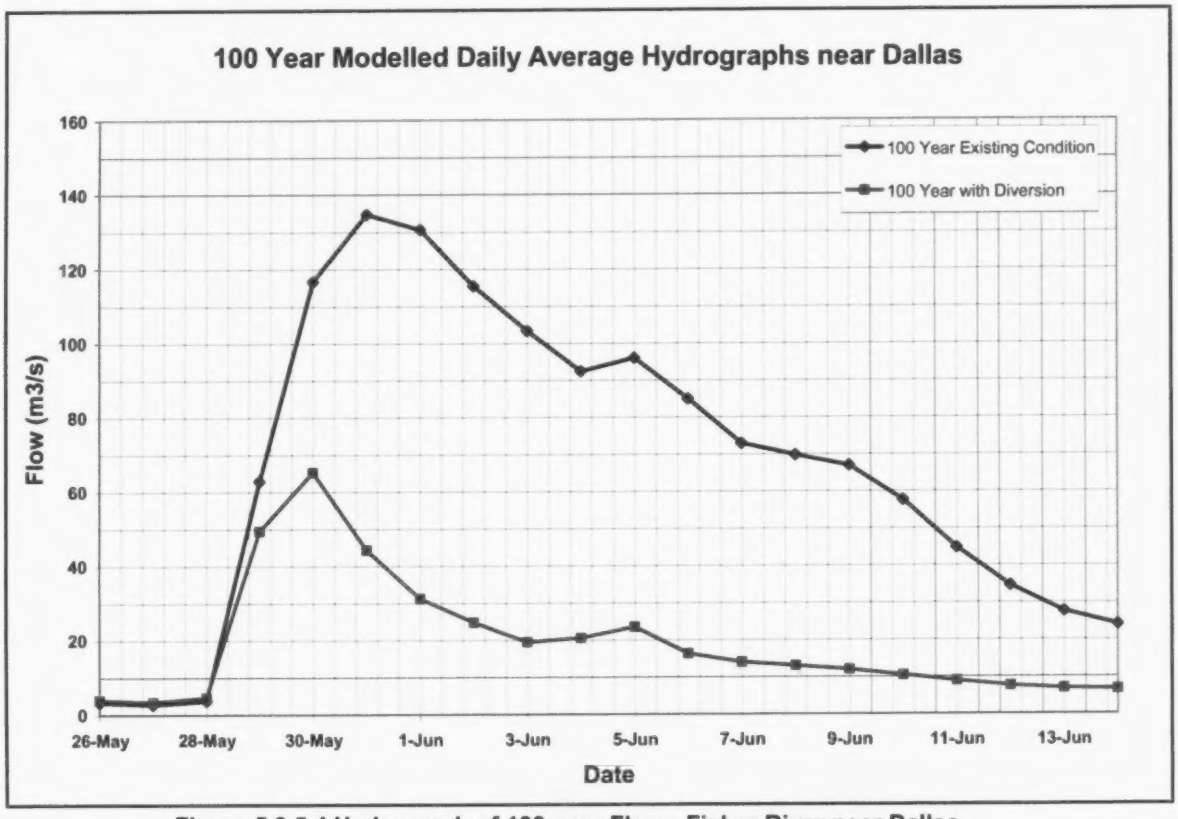


Figure 5.2.5.4 Hydrograph of 100-year Flow - Fisher River near Dallas

A hydrograph of the Fisher River existing condition 100-year flow and the flow remaining in the main stem after diversion is shown in Figure 5.2.5.4. The water level profiles for the 100-year event under existing conditions and with Mitigation Options 4 & 5 are shown in Figure 5.2.5.5.

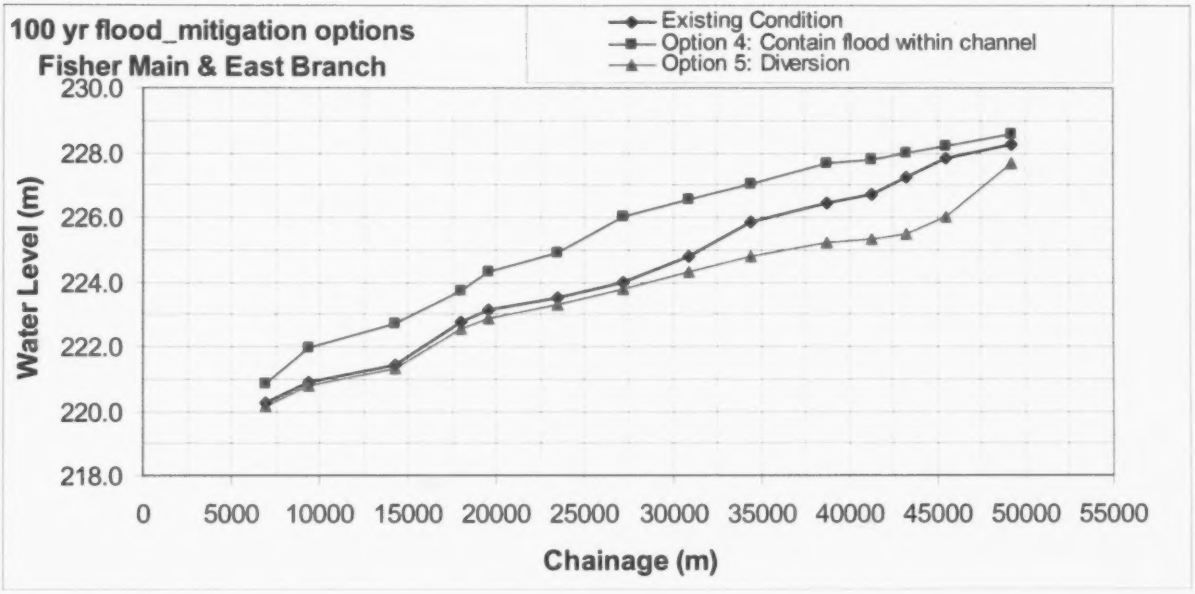


Figure 5.2.5.5 Fisher River 100- Year Hydrograph – Existing Condition & Diversion

5.2.6 Upstream Storage or Flow Throttling

Detention of runoff in upland regions is now much more thoroughly understood with the development of dynamic modelling tools. The benefit of upland detention is limited even for small events and presents economic challenges for the owner of the land on which the water is temporarily stored.

Flood mitigation by upstream detention was tested by testing an extreme condition. Certain tributaries were totally removed from the drainage network along with the corresponding catchment area and runoff volume contribution. Figure 5.2.6.1 shows the 2006 flow at the Dallas gauge after upstream catchments were removed to simulate the extreme effect of upstream storage. Due to the travel times from distant drainage areas and related timing influences there was little reduction in downstream flood peak, however the runoff volumes were reduced by this simulation. In reality the upstream storage would produce equivalent volumes over time but would delay the runoff to arrive at a time when the river flow was below peak levels. This reduction would not significantly reduce the water level, nor the flooded area, so for this reason upland detention was considered ineffective at reducing floods for this study.

Figure 5.2.6.2 shows the results of simulated upstream storage modelled with the same 2006 flows in the West Branch.

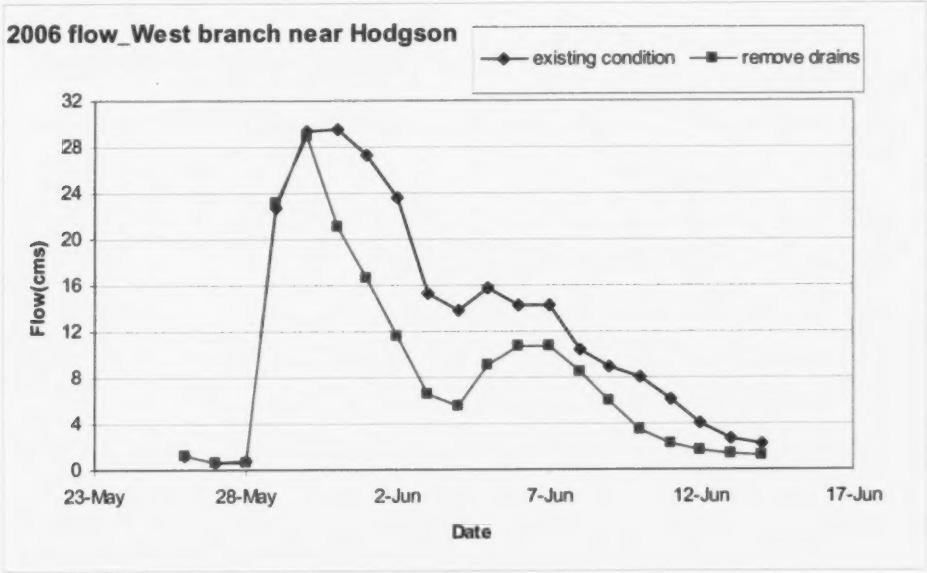


Figure 5.2.6.1 Hydrograph at Dallas Simulating Upstream Storage – 2006 Flow

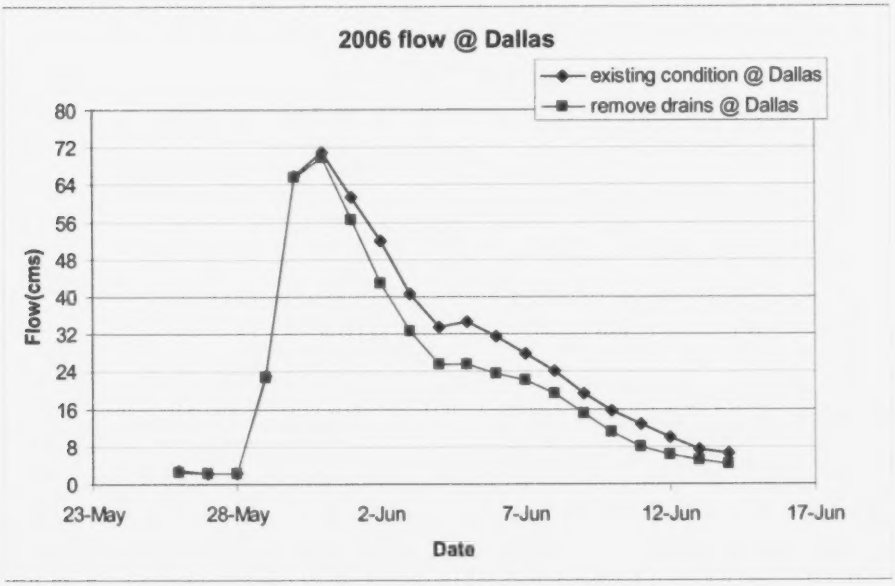


Figure 5.2.6.2 Hydrograph in West Branch Simulating Upstream Storage – 2006 Flow

5.3 Modelled Mitigation for 1% (100-year) Flood

Hydrographic impact of Options 1-6 on 1% (100-Year) were shown in the mitigation sections as Figures 5.2.3.1 and 5.2.5.5. Flood inundation regions corresponding to the mitigation options under the 100-year flood are included in GIS shp files. The flooded area depictions are based on the reasonable predictive quality of the MIKE11 model, the extrapolation of known floods to statistical extreme events, and the accuracy limits of LiDAR elevation data.

Summary tables Table 5.3.1a and Table 5.3.1b illustrate the existing condition flows and water levels at numerous locations. These tables also show the relative hydraulic benefit of the five modelled Mitigation Options.

Table 5.3.1a Fisher River Model Results for 100-year Event

Table 5.3.1 Fisher River Model Results for 100 year Event

River	Name	Chainage (m)	Existing Condition		Option 1: Low Level Crossing Replaced with 4 Box Culverts				Option 2: Install Box Culverts + Channel Clean (Gravel Removal)				Option 3: Install Box Culverts + Channel Clean + Rapids Removal			
			Water Level (m)	Flow (m^3/s)	Water Level (m)	Flow (m^3/s)	Change in Level vs Existing	Change in Flow vs Existing	Water Level (m)	Flow (m^3/s)	Change in Level vs Existing	Change in Flow vs Existing	Water Level (m)	Flow (m^3/s)	Change in Level vs Existing	Change in Flow vs Existing
Fisher River Main	Old Koostatak Croosing	6974	220.26	109	219.68	116	-0.57	6	219.68	116	-0.57	6	219.72	128	-0.54	19
	McKay Bridge	9393	220.85	107	220.75	113	-0.10	5	220.75	113	-0.10	6	220.51	125	-0.34	18
	Murdock Bridge	14322	221.39	128	221.38	131	-0.01	3	221.38	131	-0.01	3	221.34	132	-0.05	4
	Koostatak Bridge	18041	222.69	132	222.72	136	0.04	4	222.72	136	0.04	4	222.73	137	0.04	5
	Red Rose Bridge	19589	223.08	132	223.12	136	0.04	4	223.12	136	0.05	4	223.13	137	0.05	5
	Sutherland Bridge	23504	223.44	97	223.49	100	0.04	3	223.49	98	0.05	1	223.50	101	0.06	5
	Fred Stevenson Crossing	27184	223.96	96	223.93	107	-0.03	10	223.94	106	-0.03	10	223.97	119	0.01	22
	Allen Spence Crossing	30881	224.77	107	224.77	111	0.00	4	224.77	111	0.00	4	224.73	116	-0.04	9
	Old School Bridge	34452	225.73	155	225.74	158	0.01	2	225.74	158	0.01	2	225.74	158	0.01	3
	Harwill Bridge	38796	226.40	121	226.42	122	0.03	1	226.42	122	0.03	1	226.42	122	0.03	1
Fisher River West	McPherson Bridge	42085	226.69	94	226.72	98	0.03	4	226.72	97	0.03	4	226.72	97	0.03	4
	Ab's Crossing	45040	228.32	80	227.55	85	-0.77	5	227.55	85	-0.77	5	227.55	85	-0.77	5
	Hodgson Bridge-1	49137	228.45	81	228.12	88	-0.33	7	228.12	88	-0.33	7	228.12	88	-0.33	7
	Hodgson Bridge-2	49729	229.14	72	229.15	78	0.01	6	229.15	78	0.01	6	229.15	78	0.01	6
	Bridge 325	63114	238.76	73	238.02	78	-0.74	5	238.02	78	-0.74	5	238.02	78	-0.74	5
	Annette Bridge	65908	239.42	74	239.30	78	-0.12	4	239.30	78	-0.12	4	239.30	78	-0.12	4
Fisher River East	Spence	41330	226.68	124	226.69	123	0.00	-1	226.69	123	0.00	-1	226.69	123	0.00	-1
	Thomas Spence Bridge	43261	227.12	129	227.12	129	0.00	0	227.12	129	0.00	0	227.12	129	0.00	0
	Les Daniels	45544	227.84	146	227.84	147	0.00	0	227.84	147	0.00	0	227.84	147	0.00	0
	Bear Bridge	49259	227.95	130	227.95	130	0.00	0	227.85	130	-0.10	0	227.95	130	0.00	0

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Table 5.3.1b Fisher River Model Results for 100-year Event

Table 5.3.1 Fisher River Model Results for 100 year Event

River	Name	Chainage (m)	Existing Condition		Option 4: Contain Flood within Channel by Diking				Option 5: Diversion to Reduce Flow to Approximately 70 m^3/s at Dallas Gauge			
			Water Level (m)	Flow (m^3/s)	Water Level (m)	Flow (m^3/s)	Change in Level vs Existing	Change in Flow vs Existing	Water Level (m)	Flow (m^3/s)	Change in Level vs Existing	Change in Flow vs Existing
Fisher River Main	Old Koostatak Crossing	6974	220.29	112	220.82	247	0.56	138	220.15	101	-0.14	-11
	McKay Bridge	9393	220.88	110	221.80	237	0.95	129	220.71	101	-0.18	-9
	Murdock Bridge	14322	221.43	129	222.61	236	1.22	108	221.30	109	-0.13	-20
	Koostatak Bridge	18041	222.70	134	223.66	236	0.97	104	222.47	110	-0.23	-23
	Red Rose Bridge	19589	223.10	134	224.06	234	0.98	102	222.83	107	-0.27	-27
	Sutherland Bridge	23504	223.46	98	224.57	212	1.13	115	223.21	94	-0.25	-3
	Fred Stevenson Crossing	27184	223.96	96	226.00	193	2.04	96	223.77	68	-0.20	-28
	Allen Spence Crossing	30881	224.78	107	226.53	190	1.76	83	224.29	68	-0.49	-40
	Old School Bridge	34452	225.73	157	226.71	192	0.99	37	224.76	58	-0.97	-99
	Harwill Bridge	38796	226.41	122	227.38	207	0.99	86	225.16	47	-1.25	-75
Fisher River West	McPherson Bridge	42085	226.72	97	227.72	90	1.03	-3	225.40	31	-1.31	-66
	Ab's Crossing	45040	228.34	87	228.36	83	0.04	3	226.85	9	-1.49	-78
	Hodgson Bridge-1	49137	228.49	88	228.49	84	0.04	3	228.05	89	-0.44	1
	Hodgson Bridge-2	49729	229.24	79	229.20	82	0.06	10	229.16	80	-0.08	1
	Bridge 325	63114	238.78	73	239.14	84	0.37	11	238.78	73	0.00	0
	Annette Bridge	65908	239.43	75	239.694	82	0.27	8	239.43	75	0.00	0
Fisher River East	Spence	41330	226.69	124	227.86	137	0.74	8	225.33	20	-1.36	-104
	Thomas Spence Bridge	43261	227.12	129	228.19	143	0.35	-4	225.42	19	-1.71	-109
	Les Daniels	45544	227.84	146	228.26	130	0.31	0	226.01	13	-1.83	-133
	Bear Bridge	49259	227.95	130	228.26	130	0.31	0	227.28	135	-0.67	5

6. Causes of Flooding

6.1 Factors Contributing to Fisher River Flooding

Flooding in any watershed is the result of numerous causes. The Fisher River is prone to flooding from natural causes due to the orientation of the river, topographic features left after glacial retreat, grade changes, rapids and ice damming.

The ice damming is aggravated by the north-eastward orientation of Fisher River. In the spring ice in the river jams at bridges, rapids and at its Lake Winnipeg outlet may contribute to flooding problems independent of large flow events.

This study was also concerned with changes in flood magnitude attributed to influences of regional development. The analysis of the watershed changes and how this has affected flood peaks has been the subject of several studies over the past 25 years. Most have been inconclusive regarding causes of flooding as related to changes in land use or drainage network extent. AECOM has carefully examined the variety of issues that must be addressed and has developed an approach that measures the impact of land clearing and drainage improvements on flooding.

This study focussed on changes within the watershed falling into two categories; drainage improvements and land use changes. Drainage improvements can potentially speed the conveyance of runoff from the sub-watersheds to the Fisher River. Land use changes could alter the pattern of snow accumulation, snowmelt processes and the amount of water absorbed into the soil.

6.2 Drainage Network Changes

The MIKE 11 model was used to assess the impact of extending the drainage network. The geometry of drainage channels within the calibrated existing condition model were modified to reflect as much as possible the stream conditions in the mid 1960's before the FRED program provided funding for drain expansion. The cross-sections of existing streams in locations identified as having been added since the 1960's were adjusted to simulate shallow swales with no culverts or roads.

The net result of this model simulation was to increase the magnitude of flow peaks at the Fisher River gauge near Dallas. This result was considered counter-intuitive and may have overlooked the throttling impact of existing culverts and bogs. The model required more refinement to simulate the relative ineffectiveness of areas without drain network improvements.

To determine the sensitivity of the model to drainage improvements through network extension, an extreme network analysis was considered. This was simulated by total removal of newer drains through stream truncation in the model. As a result, this also eliminated the contributing runoff from the areas serviced by these newer drains. The result of area removal from the west branch produced no noticeable change in the flood peak for the 2006 event, but reduced by 22% the total volume of flow passing the

Dallas gauge. The result of stream truncation and subsequent contributing area removal from the East Branch produced a corresponding small change in flood peak and a smaller change in volume (4%) for the 2006 event. For smaller runoff events, the upstream storage produced a small reduction in flood peak at the Dallas Gauge.

Based on this extreme case analysis, upstream storage was considered ineffective at reducing large magnitude flood peaks. Further refinement of the network for this purpose was not modelled.

6.3 Land-Use Changes

The impact of land use changes was assessed by using information from provincial and federal GIS databases. The analysis was studied by adjusting the aggregated CN for the sub-catchments corresponding to measurable land use changes.

Due to sensitivities in First Nations communities and the fact that this information may be used to assess changes in flood damages, a great deal of care was taken to configure the model as physically accurate as possible. Technical accuracy of the model, proper documentation and trustworthy results were considered essential to developing trust at the First Nations and Local Government advisory committee level as well as by other levels of government.

The land use database from 1966 was analysed to determine the conditions before 1970, the year commonly noted for an increase in flooding. The 1966 historic land-use was downloaded from the Canadian Land Inventory (CLI) and was presented in five classifications. The present land-use (2002) was downloaded from the Manitoba Land Initiative (MLI) with significantly more detail and grouped in 16 classifications. To determine the impact of land use change, it was necessary to define common classification groupings. These classifications were determined in dialogue with MWS and the provincial hydrologist.

The historic conditions were simulated by modifying the land use in the Fisher River basin for one of the calibration years using the existing condition configuration of the MIKE 11 hydraulic model. This allowed the impact of land use changes to be quantified separately from land drainage.

Representative SCS (Soil Conservation Service) Curve Number (CN) were selected for use in this land use analysis. Table 6.3.1 below illustrates the aggregation of land-use classifications from the modern land use data to matching historic land use classes.

Table 6.3.1 Land Use Classifications and Class Merging

CROSS - REFERENCE TABLE FOR LANDUSE CLASSIFICATIONS

CATEGORY	LAND USE or LAND COVER														
MWS	AGRICULTURE	GRASSLAND	WOODLANDS (FORESTED AREAS)						WATER			OTHER			
MLI DESCRIPTION	CROPLAND	GRASSLAND/ RANGELAND	DECIDUOUS FOREST	MIXEDWOOD FOREST	CONIFER FOREST	BURNS	OPEN DECIDUOUS FOREST	FOREST CUT BLOCKS	[illegible]	[illegible]	[illegible]	TREED ROCK	CULTURAL	BARE ROCK / SAND / GRAVEL	ROADS / TRAILS
MLI CODE (2002)	1	12, 4	2	5	9	10	11	14	3	6, 17	7	8	13	15	16
CLI (1966)	H, G, A	P, K	T,U						-	M		O, S, L, B, E			
Curve No.	76	69	60						95			92			

Soil type, land use and slope were queried for each sub-catchment and an area weighted average Curve Number generated for each catchment for the year being considered. A shift in land use was noted in the watershed. Present land use in the watershed is predominantly woodlands 34.8% with agriculture and grasslands forming approximately 17.3 and 29% on better drained portions of the watershed and other uses including marsh, water and built-up areas forming roughly 18.9%.

The net change in land use was a shift from woodland to grassland or forage. Woodland was reduced from 52.5% in 1966 to 42.4% in 2002. A corresponding shift was noted in grassland and forage crops with an increase from 30.7% in 1966 to 41.8% in 2002. Water bodies or wetlands reduced from 16.6% in 1966 to 14.0% in 2002. The impact on aggregate CN was noted as shown in Table 6.3.2 below.

Table 6.3.2 Land Use Change - Area Analysis 1966 & 2002

UMA Analysis

CHANGE IN LAND USE DISTRIBUTION FOR:

WHOLE FISHER RIVER WATERSHED USING BOUNDARY AS PROVIDED BY UMA (DEC 2007)

UMA Classification	AGRICULTURE	GRASSLAND	WOODLANDS		OTHER	TOTALS
AREAS IN 1966	373	250	1065	337	1	2026
AREAS IN 2002	409	439	860	283	35	2026
CHANGE IN AREA (SQ KM)	36	189	-205	-54	34	0
CHANGE AS % OF TOTAL AREA	1.8%	9.3%	-10.1%	-2.7%	1.7%	0.0%

Table 6.3.3 Land Use Change - CN Analysis 1966 & 2002

1966 Landuse Area

CLI Code	Classification	Area (km2)	Percent	Current CN
B	Built-up Areas	1.05	0.1%	92
A	Cropland	373.01	18.4%	76
P	Improved pasture and forage crops	149.61	7.4%	69
T	Productive woodland	1065.33	52.6%	60
K	Rough grazing and rangeland	100.82	5.0%	69
M	Swamp, marsh, or bog	336.51	16.6%	95
	Total	2026.33	100.0%	69.9
	Percent increase in CN from 1966 to 2002			1.0%

2002 Landuse Area

	Classification	Area (km2)	Percent	Current CN
1	Agriculture	409.05	20.2%	76
2	Deciduous Forest	100.32	5.0%	60
3	Water	34.08	1.7%	95
4	Grassland	412.97	20.4%	69
5	Mixedwood Forest	75.47	3.7%	60
6	Marsh	208.20	10.3%	95
7	Bogs	40.29	2.0%	95
8	Treed Rock	0.00	0.0%	92
9	Conifer Forest	24.65	1.2%	60
10	Burnt Areas	0.00	0.0%	79
11	Open Deciduous Forest	658.56	32.5%	60
12	Forage Crops	26.18	1.3%	69
13	Cultural	1.14	0.1%	92
14	Forest Cutblocks	1.18	0.1%	60
15	Bare rock/sand/gravel	1.07	0.1%	30
16	Roads/Trails	33.18	1.6%	92
	Total	2026.33	100.0%	70.6

The measurable changes in land use reflect what was perceived by the community to be occurring as a result of development of increased agricultural activity at the expense of woodland and natural wetland storage. Figure 6.3.1 shows the modelled hydrograph results from the various combinations of present versus historic land use and drainage network. A small change is evident in flow peak for the 2006 runoff event. Figure 6.3.2 shows the water level impact from these small flow rate changes for the 2006 runoff event.

Hydraulic model results for the 2006 conditions are summarized in Table 6.3.4. These results show small increases in runoff volume, mean daily and instantaneous peak flows, and mean daily water levels at the Dallas gauge.

Table 6.3.4 Hydraulic Impact of Land Use and Drainage Change - Fisher River 2006 Conditions

	1960s Conditions	Present Conditions	Change
Volume near gauge (Dam^3)	45,042	47,309	5.0%
Peak (daily mean m^3/s)	69	71	2.9%
Peak (instantaneous m^3/s)	73	74	1.4%
Peak Water Level (m)	223.37	223.39	0.02

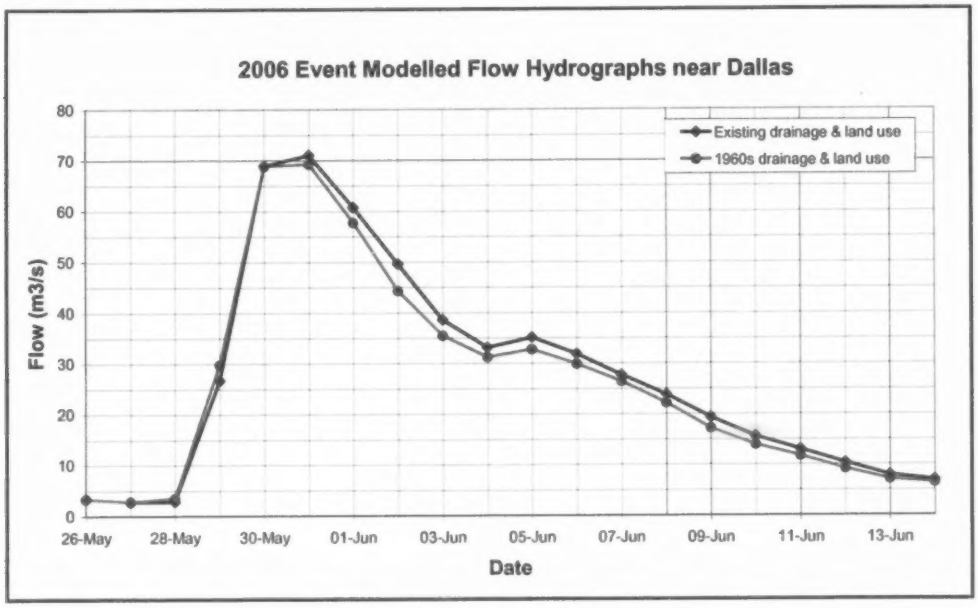


Figure 6.3.1 Fisher River 2006 Flow Hydrograph

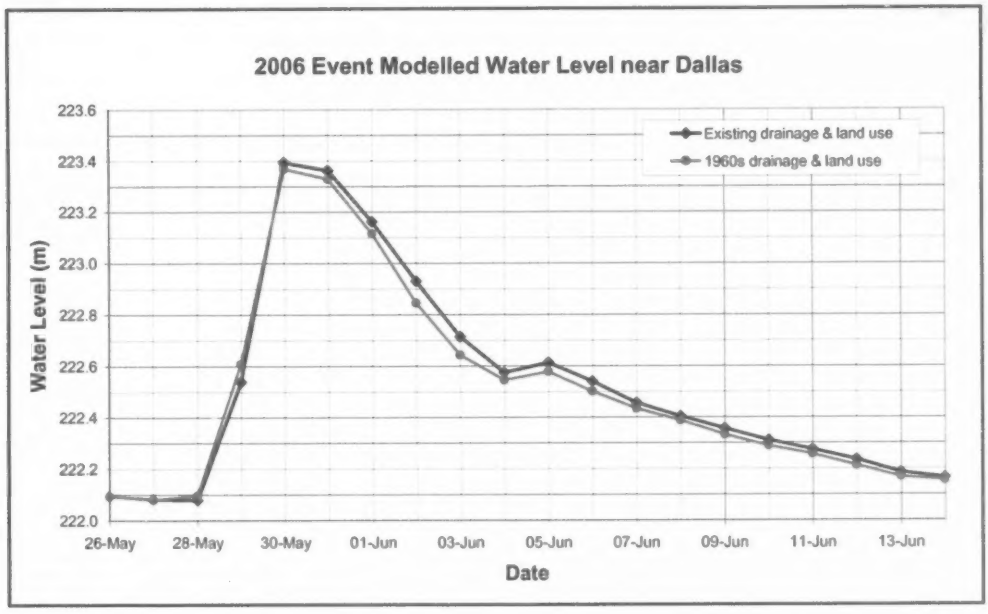


Figure 6.3.2 Fisher River 2006 Water Level Hydrograph

Table 6.3.5 summarizes hydraulic model results for the 100-year conditions. Model results show small increases in runoff volume, mean daily and instantaneous peak flows and mean daily water levels at the Dallas gauge.

Table 6.3.5 Hydraulic Impact of Land Use and Drainage Change - Fisher River 100-year Conditions

	1960s Conditions	Present Conditions	Change
Volume near gauge (Dam^3)	111,628	116,085	4.0%
Peak (daily mean m^3/s)	128	135	5.5%
Peak (instantaneous m^3/s)	135	141	4.4%
Peak Water Level (m)	223.977	223.983	0.007

The results of simulations for the 100-year event are illustrated on Figures 6.3.3 and 6.3.4.

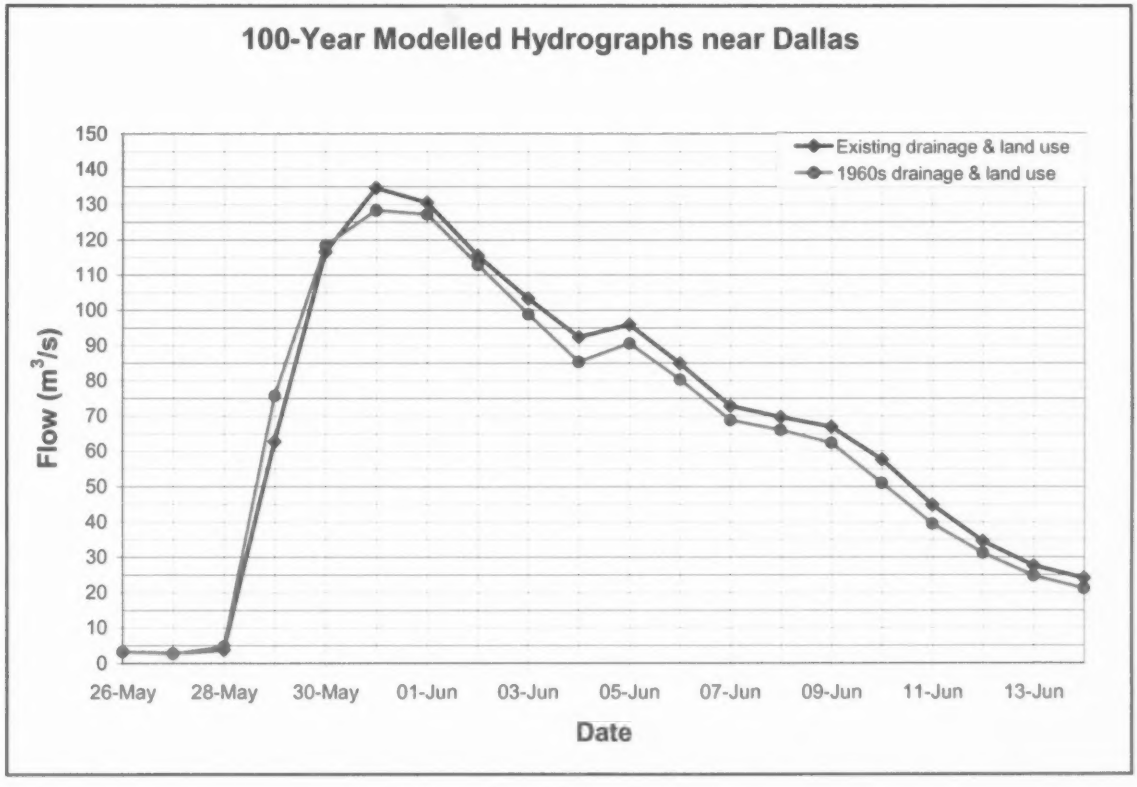


Figure 6.3.3 Fisher River 100-year Flow Hydrograph

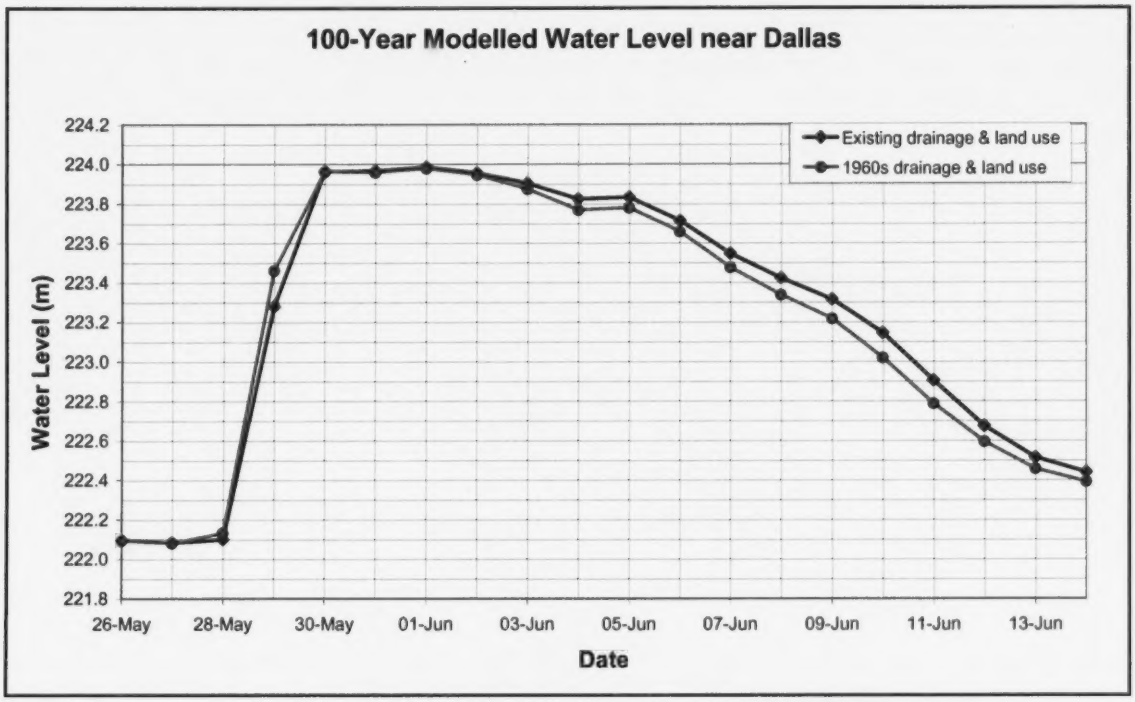


Figure 6.3.4 Fisher River 100-year Water Level Hydrograph

In summary this analysis of changes to land use and drainage network from 1966 to 2006 indicates that:

- Crop land increased 1.8%
- Grassland increased 9.3%
- Forest was reduced 10.1%

These changes do not add up to zero due to a significant increase in the category of "Other". This catchall category which represents cultural features such as towns and roads shows an increase from 1km^2 to 35km^2 or 1.7% of the total watershed. It is believed that this represents a change in definition rather than an actual change in land use.

The analysis has indicated that land use changes and drainage improvements has had little impact on peak water levels or flood duration for extreme events at downstream locations in the First Nation Communities.

7. Economic Analysis

The impact of flooding on the affected communities is significantly greater than what can be measured by economics alone. The social, physical and psychological impacts of flooding are difficult to measure with engineering tools and outside the scope of this study. However, for the purpose of measuring the effectiveness of various mitigation measures, economics were considered a fair representation of cost. This study focussed on defining the flood inundation zone and counting the cost of flooded property under existing conditions, then observing relative reductions of flood zone extent and depth to determine mitigation recommendations based on construction costs and economic benefit measured as property damages averted.

7.1 Asset Evaluation

Flood claims for homes and infrastructure were requested from the first nations and rural communities. It was assumed that the value of infrastructure and damage costs for representative flood events would be made available by the affected rural municipalities, communities and First Nations. This information was to be supplemented by damage claims to the Manitoba Emergency Measures Organization. This economic impact data was made available for only a few flood events and in sporadic regional distribution such that this did not provide a comprehensive representation of the total impact of a given flood. For this reason economic evaluation was based on available property location data developed from First Nations asset maps and aerial photos supplied by the Peguis First Nation, Fisher River Cree Nation and the Department of Indian and Northern Affairs Canada (INAC).

Property maps were available from Peguis First Nation. These maps were digitized and the building area of residential and public assets associated with the GIS point representing the location of the residence or community building. INAC provided additional GIS property asset information from recent Asset Condition Report System (ACRS) documenting location and area of community buildings.

A detailed inventory of residential assets was provided by Peguis First Nations. This data included residential living area, outbuildings, garages and basements. To balance the level of information available in other areas, the building footprint or main floor living area was analyzed for all Peguis First Nation residences.

Fisher River had detailed aerial maps which provided sufficient detail to locate homes in the community within the flood risk area. Aerial photo updates dated 1998 for Fisher River and 2003 for Peguis were made available from INAC. These colour photos were more recent than those available at MLI and facilitated an updated inventory of residential buildings. Asset Condition Report System (ACRS) reports for Fisher River were to be delivered in February 2008. However, these reports were not available at the time of this report. Houses in the northern community of Dallas were included in the economic review based on digitization of air photos.

Residential living areas were assessed on available data and estimates extrapolated to areas where residential living area was not supplied. Residential living areas data was supplied by Peguis First Nation. Since residential living area data was not supplied for Fisher River Cree Nation, an estimate was generated from statistics of the Peguis properties. Peguis residences had an average main floor living area of 1117 m^2 per independent living unit. This value was applied to the Fisher River residential units supplied by INAC ACRS files and other homes visible on more recent aerial photographs.

Residential property losses were based on estimated unit cost applied to the main floor living area. Asset values were suggested in the 2005 Cost Reference Manual provided by INAC. The unit price for residential assets (Rural, four bedroom, with basement) was suggested as 1,207 $/m^2$. This value was adjusted by CRM prescribed formulae for location, annual inflation and other factors to 1,610 $/m^2$. This was considered too low and a more representative value was generated based on analysis of recent construction cost estimates provided by Peguis First Nation and recent costs for ready-to-move homes and servicing. A value of 2,045 $/m^2$ (190 $/ft^2$) was used in this economic evaluation for homes flooded to depths exceeding 0.6m to simulate total loss of home and contents, including basement storage. A value of 430 $/m^2$ (40 $/ft^2$) was used for homes flooded to depths below 0.6m to simulate loss of basement contents.

Business and community buildings in Peguis and Fisher River were assessed on available area supplied in INAC asset files. Property values were assessed based on CRM recommended values inflated to reflect location and year.

Table 7.1.1 Representative Property Values

PROPERTY TYPE	UNIT VALUE $/ft^2$	UNIT VALUE $/m^2$
RESIDENTIAL	190	2045
BASEMENT	40	430
SHED	40	430
GARAGE	40	430
BARN	40	430
GRAIN_BINS	100	1076
MACHINE_SHED	100	1076
COMMERCIAL	220	2368
PUBLIC	220	2368

Members of TAC informed the study team that Fisher River Cree Nation had largely completed flood proofing of home in their community. The number of homes already raised and their location were not provided, so the study team made an assumption that homes in the flood risk area were all raised to the Hydro Severance line of 725' (220.98 m). Homes identified to be in the zone below the 725' LiDAR contour were removed from the flooded area house count. Figure 7.1.1 shows an example in Fisher

River residences within the proposed dyke alignment. The figure also shows the homes that were assumed to be on elevated pads protected against extreme static Lake Winnipeg levels.

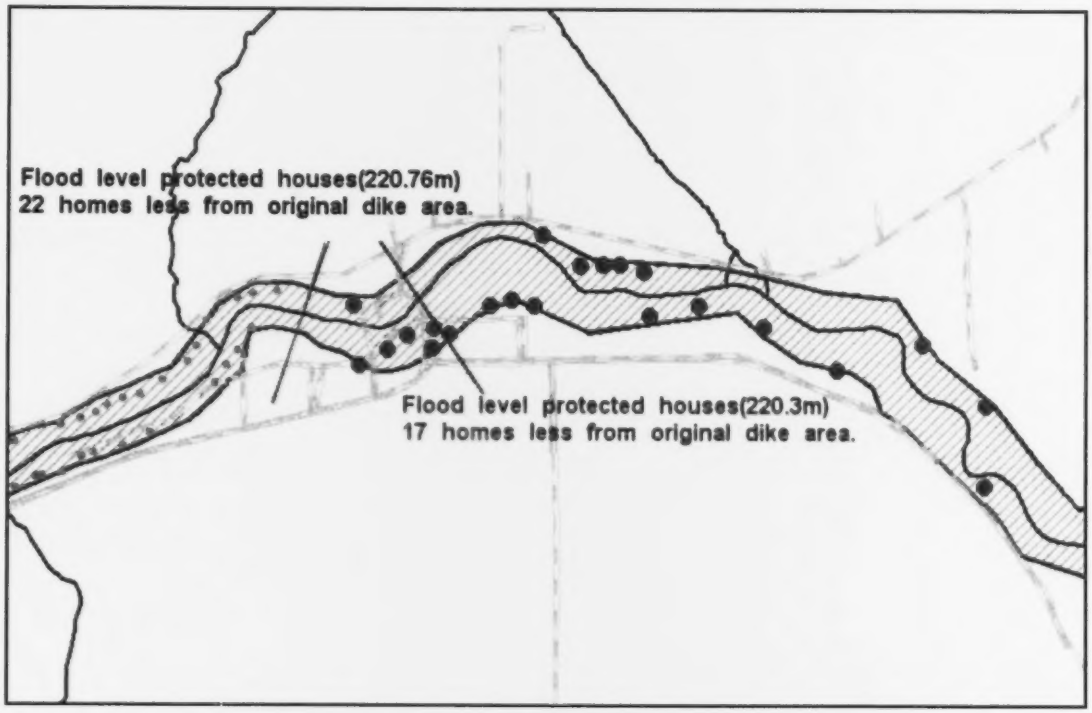

Flood level protected houses(220.76m)
22 homes less from original dike area.
Flood level protected houses(220.3m)
17 homes less from original dike area.

Figure 7.1.1 Properties Inside Conceptual Dyke Alignment

The value of flooded lands and crop losses were not supplied and were not quantified. TAC members from Peguis First Nation provided an estimate that 23,000 acres flooded in a typical year. Their estimate of crop damages paid out was $50 / acre. This amounts to $123 / hectare, however this unit value was not included in economic analysis, due to the late timing of data provision. Any additional damaged attributed to the 100-year base case and reduction due to flood mitigation would raise the value of the benefit by a maximum amount of $1.15M.

Infrastructure damages were not supplied on a comprehensive basis to allow thorough analysis. Numerous intangible costs are incurred by flood events including increased burden on community social services, emergency services, health and safety concerns and lost economic opportunity costs. Although these are considered significant, they could not be taken into account for this economic evaluation.

7.2 Economic Benefit and Cost Evaluation

The economic analysis assessed the costs and benefits of all the flood mitigation alternatives. MIKE 11 simulations indicated both the aerial extent and depth of flooding. The existing property damage values corresponding to the 100-year flood were estimated under existing river conditions using the standards established in Manitoba after the 1997 Red River flood. Residential assets were considered a total loss when water depth reached the floor joist elevation. This water level was assumed in the model as 0.6m flood depth at the foundation based on available LiDAR elevation data. Partial losses (in the order of 20%) were estimated to reflect costs of flooded basements and other issues with flooding where depth at the foundation was between 0 and 0.6m deep. Reduction in damages associated with each mitigation alternative was defined as the benefit.

The same techniques were to be used to assess the change in flood damages as a consequence of the increased land drainage and land use changes occurring within and upstream of the Peguis and Fisher River Cree Nation lands. As discussed in Section 6.0 the simulated water levels for the "pre-drainage" period were very close to existing condition water levels. As discussed in Section 6.0 the simulated water levels for the pre-drainage period were approximately the same as the existing condition and no further assessment was attempted to determine "additional damages" attributable to man-made changes to the watershed.

To simplify the economic evaluation of flood damages, a property was considered flood affected and the value counted as lost when a property was located within the defined flood zone for a given scenario. Limited flood claim data in the first nations and surrounding communities prevented comprehensive analysis of infrastructure losses corresponding to floods of a given magnitude. For this reason the flood cost was attributed to building asset flooding only.

Peguis reported on average 43 homes are protected from flooding each year with 100 on stand-by each year depending on water levels. According to Department of Aboriginal and Northern Affairs briefing notes (Feb. 21,'03) EMO claims and receipts for Peguis flood damages totalled 4.6 $M in the years 1996 to 2000. Average annual flood fighting costs were not available. Costs associated with home relocations out of the floodplain or raising onto elevated pads constructed on site were estimated to range between $40,000-70,000. A unit cost of $60,000 was used to estimate the cost of raising all flood affected homes in the regions flooded by dyke constriction. Cost related to the social inconvenience of flooding, including: additional school bus transportation; temporary shelter; health-related costs; etc. could not be quantified, but were considered to be a significant burden to the communities and residents affected.

The costs of the flood mitigation alternatives were determined to a "feasibility study" level. Construction costs for alternatives were estimated based on recent tendering costs for major projects in Manitoba, standard engineering procedures for estimating earthwork or other construction activities, and land values based on the most recent assessment.

A summary of the mitigation options hydraulic impact, construction cost estimate and associated property losses averted is presented in the following table. The Benefit Cost Ratio is included for reference and selection of options considered feasible based on the limited economic data analyzed in this study.

Table 7.2.1 Mitigation Option Cost Estimates and Assumptions

Mitigation Options		Cost Estimate	Notes
Option 1	**Box culvert**	**$2,200,000**	Cost does not include Old Koostatak crossing replacement by bridge of 8-box culvert.
Option 2	**Box Culvert + Channel Clean Out**	**$2,300,000**	Does not include new bridge or 8-box culvert costs. Earth excavation unit price $5/m^3
Option 3	**Box Culvert + Channel Clean + Rapids Removal**	**$5,100,000**	Does not include new bridge or 8-box culvert costs. Till excavation unit price assumed $10/m^3
Option 4	**Dyke**	**$20,900,000**	Dyke elevation was set with 1.5m freeboard
Option 4b	**Dyke & Homes Raised**	**$35,700,000**	Dyke elevation at WL+1.5m freeboard. All homes in dyke raised at $60,000 each
Option 5	**Diversion**	**$196,300,000**	Diversion excavation volume was estimated based on contour elevations

The table states assumptions built into the estimates. Notable exclusions would be the estimate for a replacement structure at the Old Koostatak Bridge (in the order of $4.5M) versus an eight Box Culvert low-level crossing replacement (in the order of $1M). Earthworks related to diversion was set at 5 $/m^3 based on recent estimates of major construction projects in the province, and tender bids for smaller jobs throughout the province. Significant cost is incurred in the diversion option, due to the significant length and size required to reduce the flows to within channel capacity. Unit cost for rapids removal was set at $10/m^3 based on recent information suggesting a till base in the Murdock bridge drawing, not rock as assumed earlier. This results in a cost of rapids removal in the order of $1.9M for the 2.4 km excavation length to a 1.4m depth at crest of ridge.

The study team analysed the first cut results of Benefit Cost Ratio (BCR) and found that results for the Dyke Mitigation Options were in the 0.9 to 1.3 range. The study team proceeded to determine sensitivity of the BCR to damage curve shape. Conservative values where used to estimate a minimum benefit, compared to cost and still resulted in BCR above unity. These values shown in Table 7.2.1 were presented at the eighth TAC meeting. Values updated since the 8th TAC meeting were Option 4b which adds the cost of replacing all constraining bridges at a capital cost of $18.7 million.

Without rerunning of the flooded area model, a comparison was made of the 100-year water level with the 2006 water level under mitigations conditions. This was an effort to determine the range of flood damage

to expect with dyke mitigation and diversion under 2006 flow conditions. The assumption was made that minimal damage $2M would occur with all at-risk homes raised onto pads, $1M would occur with all homes raised onto pads and FR1 Rapids excavated. A further assumption was made that 0% of 2006 damages under existing conditions would occur on the 7.5 Year return period, 10 Year damages would be the average between 7.5 Year and 100-year. In any case the BCR remained just slightly above unity for the Dyke options.

It is recognized that further refinement of dyke alignment and home raising would reduce the losses due to flooding inside the dyke, and therefore raise the benefit, without significant increase in dyke volume or cost, and the BCR would remain above unity.

Table 7.2.2 Benefit Cost Analysis for Mitigation Options

Mitigation Option	Option	Capital Cost	Annual Maintenance Cost	Annual Capital Cost of Works	Annual Cost with Maintenance	Annual Damages Averted	B/C Ratio
Dyke with Ex. House Pads	4	$20,823,000	$478,929	$1,140,616	$1,619,545	$1,876,045	**1.16**
Dyke & New House Pads	4b	$35,643,000	$478,929	$1,952,407	$2,431,336	$2,641,200	**1.09**
Dyke, Pads & Rapids Removal	4c	$36,363,000	$478,929	$1,991,846	$2,470,775	$2,717,033	**1.10**
Dyke & New House Pads & New Bridges	4d	$54,954,573	$478,929	$3,010,232	$3,489,161	$2,641,200	**0.76**
Diversion	5	$196,286,000	$4,514,578	$10,751,906	$15,266,484	$2,389,323	**0.16**

The benefit/cost ratio for the diversion as proposed cannot be economically justified. Dykes and additional house-raising pads and/or relocation may prove to be the best solution to reduce flooding in the First Nations communities.

Upon presentation of these benefit/cost ratios, TAC members expressed concerns regarding the unrealistic unit values and assumptions applied to the analysis. Rationalization was presented that suggested further refinement under this scope should not be necessary given the range of options presented and that a feasible solution was provided in conceptual form. Further studies should include improved unit cost estimates and improved collection of asset records from all stakeholders in the watershed.

Additional concern was raised by Chief Hudson of Peguis First Nation that residents living on C.P. lands (property held with individual Certificate of Possession) would be reluctant to part with any property required to develop a dyke alignment Right-of-Way. If such property was to be purchased at a fair market

value assumed to be $2000/acre ($4047/ha) this would represent an additional total cost of $620,000 or less than 2% of project costs, which has no significant impact on project construction cost once discounted for the life cycle cost of the project.

Additional information on waterway openings (Bridges) at risk in the watershed was studied in a companion project and may be available upon request from Manitoba Water Stewardship. Community assessment of strategic transportation structures was not complete at the time of the report.

8. Community Presentations

The importance of the consultation process cannot be stressed highly enough. The success of this study depends not only on the technical merit of the modelling, but to a large degree on the acceptance of the study by the affected communities. It was hoped that through a process of transparent progress reporting to TAC and community review of the final report, this study would be seen as a substantive effort to resolve the local flooding issues.

AECOM met with management and TAC committees over the course of the project as required for all parties to be comfortable with the study process.

A community workshop was viewed as part of the consultation process. This presentation provided opportunity for the communities to be brought to an understanding of the scope and merits of the model study and the relative benefit of the mitigation strategies that were identified.

8.1 Summary of Community Responses

Comments from the community presentations in response to project scope, model results, mitigation options, and economic analysis were collected and summarized by an independent meeting facilitator. The summary of these community responses are included as Appendix B to this final report.

9. Conclusions

This study has achieved its objectives in that hydraulic and hydrologic modelling tools have been developed that have allowed for a comprehensive analysis of the flooding in the Fisher River watershed. This analysis has indicated that land use changes and drainage improvements have little impact on peak water levels or flood duration for extreme flood events at downstream locations in First Nation Communities. The impact of drainage is much more pronounced in the upper and middle reaches of the Fisher River where simulations indicate that water levels are increased up to 1 meter.

In spite of this conclusion, it can be stated that the First Nation Communities of Peguis and Fisher River undergo flooding more frequently and are more severely impacted than most other communities in Manitoba. The geography of the Fisher River and the locations of these communities along a low gradient section of the river, means that the land along the river is predisposed to flooding.

The only economically justified flood mitigation measure identified is dykes along both sides of the river and moving or raising homes presently located between the conceptual dyke alignment and the river. This option would prevent the majority of the flooding on the Peguis First Nation but would also raise water levels in the confined river channel for the 100-year event. This higher water level would require additional homes being raised above existing flood protection in the Fisher River Cree Nation. The alignment of the dyke would have to be optimised during final design to reduce the number of homes to be moved or raised.

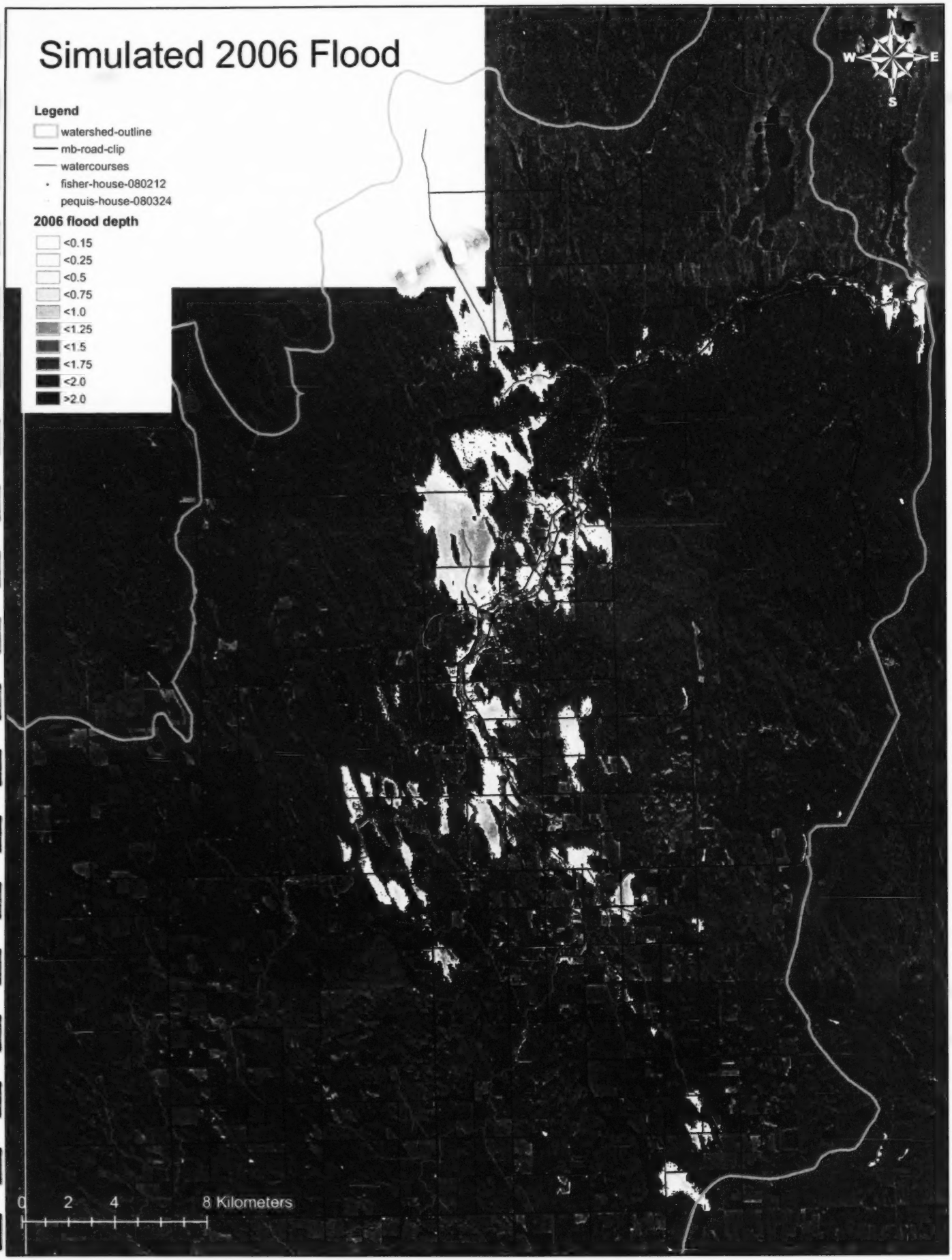
Dykes will have an impact on the required elevation of bridges as higher water levels will occur due to less water being stored on the floodplain. Higher water levels may reduce the incidence of ice jamming at rapids along the river, although this is speculative at this time.

Ice jams are a major cause of flooding within the Fisher River and further analysis of the ice formation processes should be undertaken and mitigation measures examined. These may include identifying and sealing springs that increase the volume of ice during the winter and/or containing ice within reaches of the river where there is adequate hydraulic capacity to prevent jams forming at bridges and rapid sections.

A wide range of other flood mitigation options were examined. In many cases these had a minor benefit for the 100-year open water event. Replacement of the low level crossings with more hydraulically efficient box culverts will reduce local water levels, reduce the period of time when the crossing is out of service and if properly designed will help to break pan ice and the reduce occurrence of ice jams.

Changes to a crossing may trigger compliance to the Navigable Waters Act. This may require further consideration however, a case could be made that existing conditions are being improved without expensive replacement with a bridge and total restoration to open water conditions.

Appendix A
Flooded Area Maps


Simulated 2006 Flood
Legend
watershed-outline
mb-road-clip
watercourses
fisher-house-080212
pequis-house-080324
2006 flood depth
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<0.25
<0.5
<0.75
<1.0
<1.25
<1.5
<1.75
<2.0
>2.0
N
W
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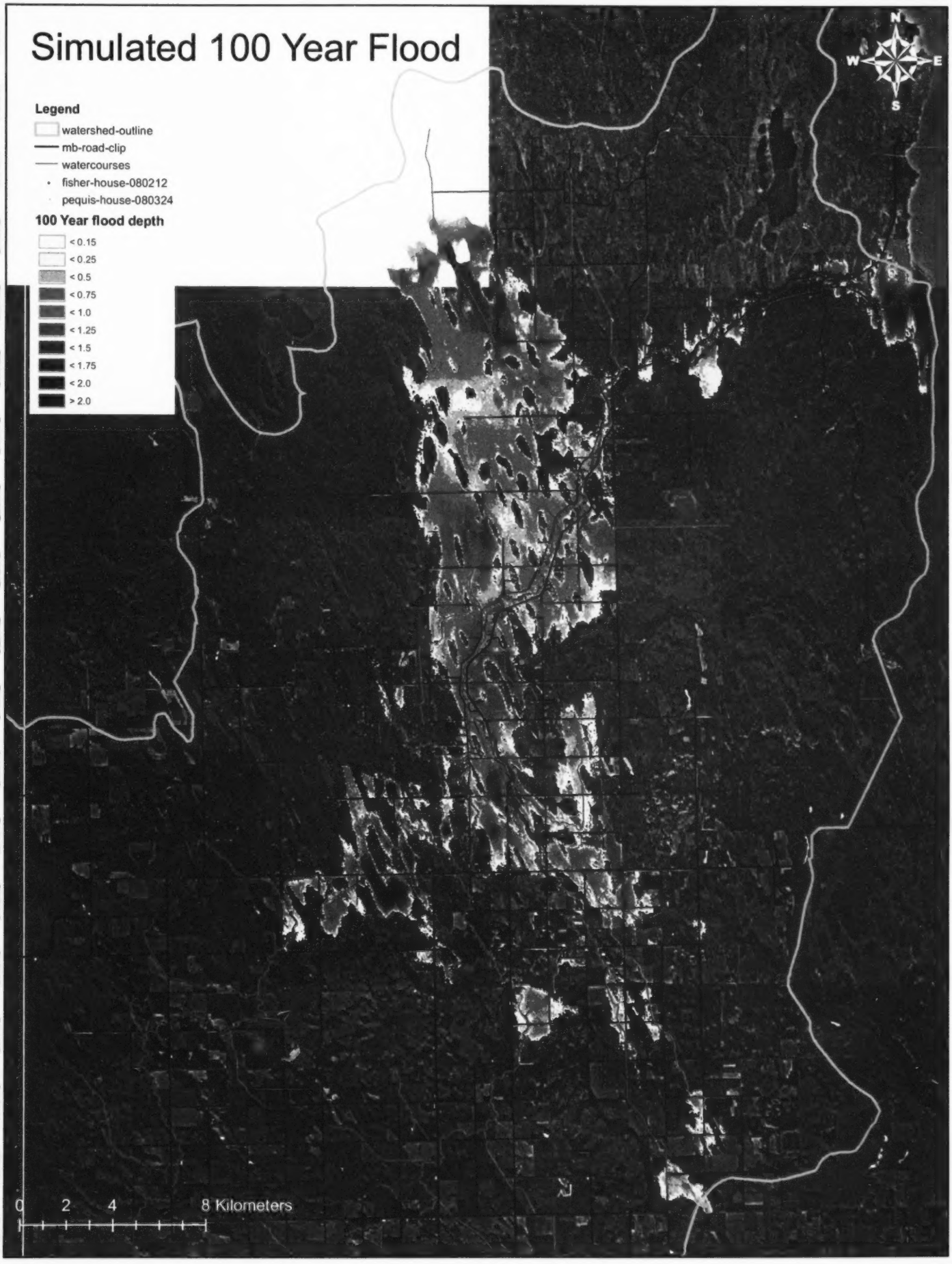
0 2 4 8 Kilometers


Simulated 100 Year Flood
Legend
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mb-road-clip
watercourses
fisher-house-080212
pequis-house-080324
100 Year flood depth
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< 0.25
< 0.5
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> 2.0
N
W
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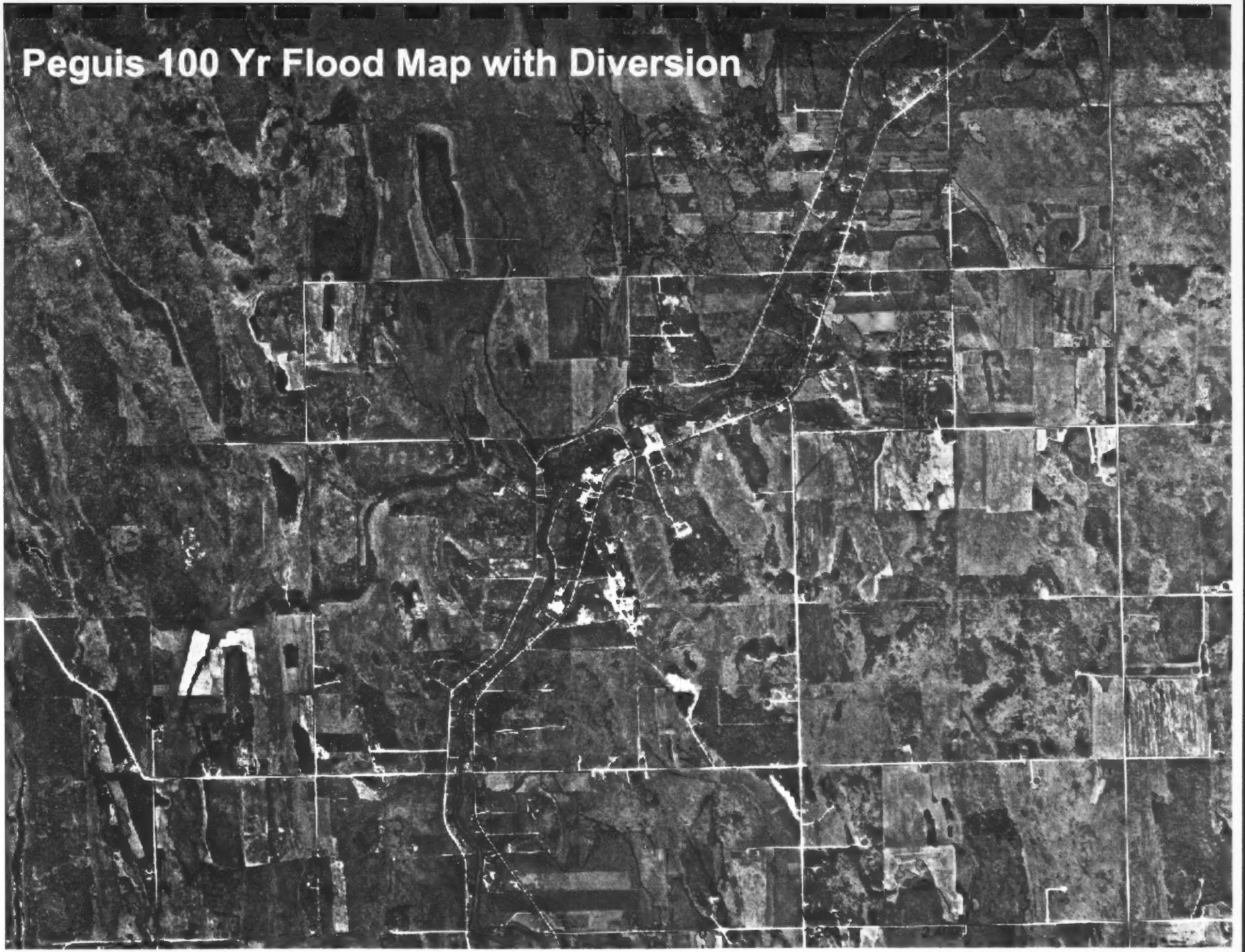
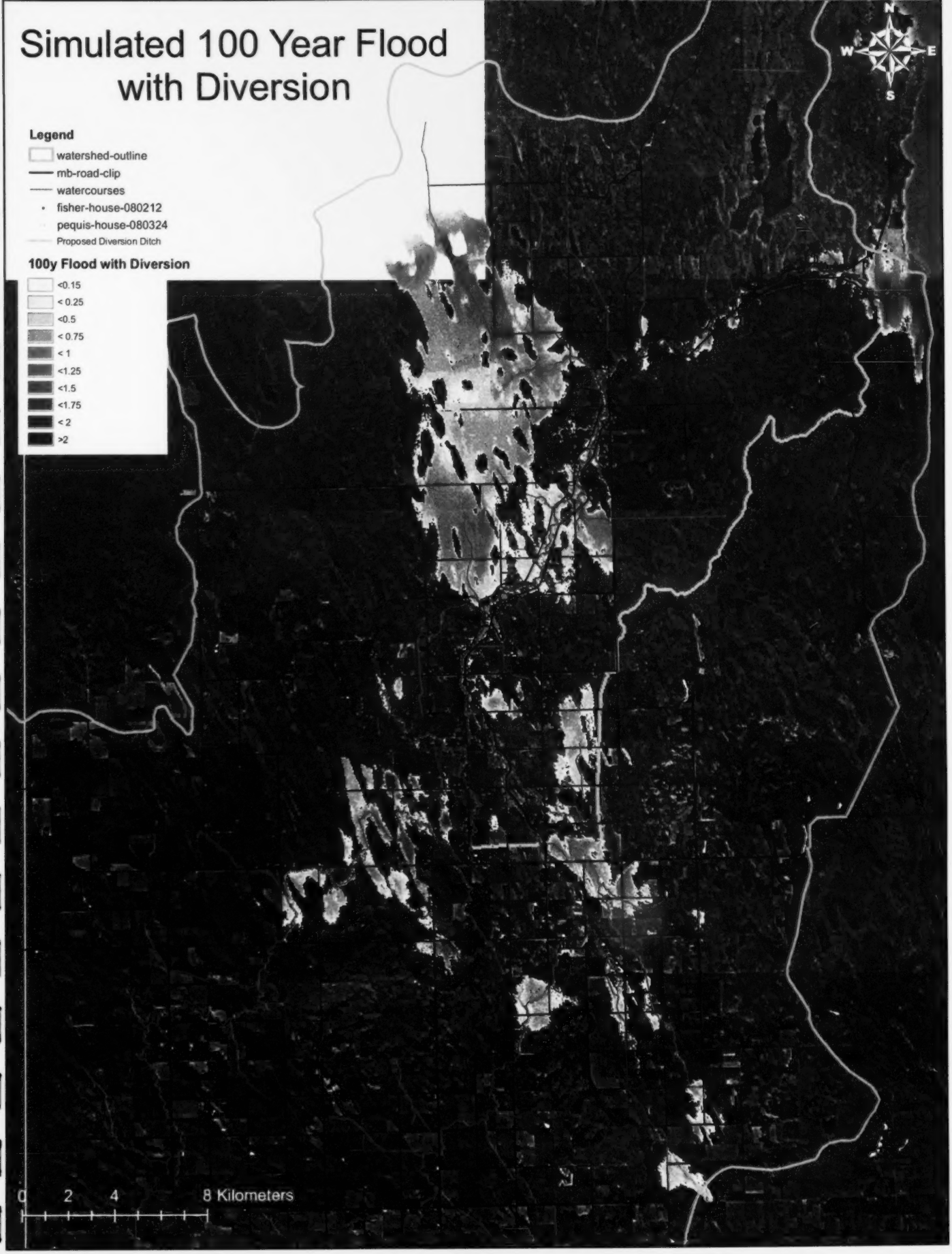
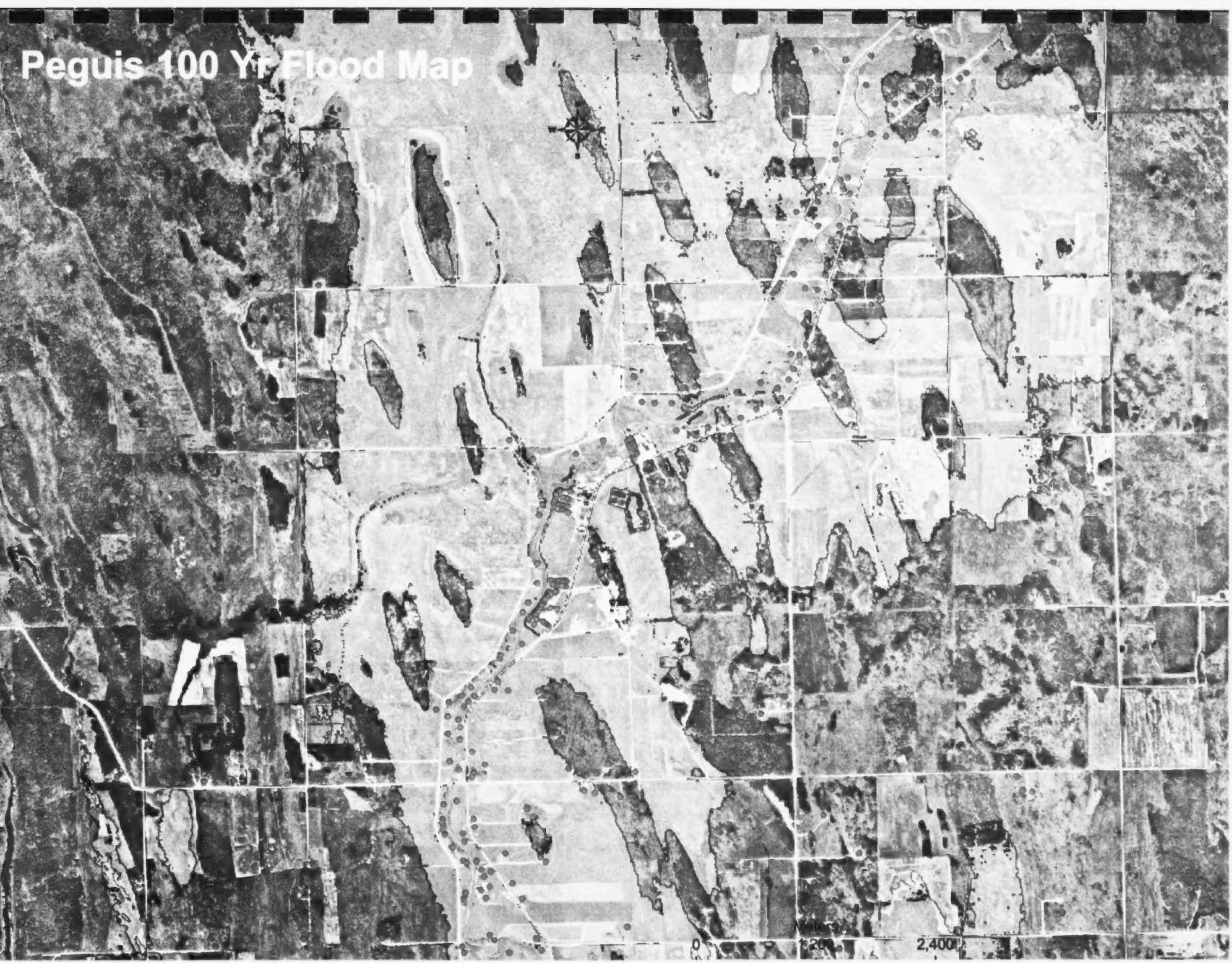
S
0 2 4 8 Kilometers

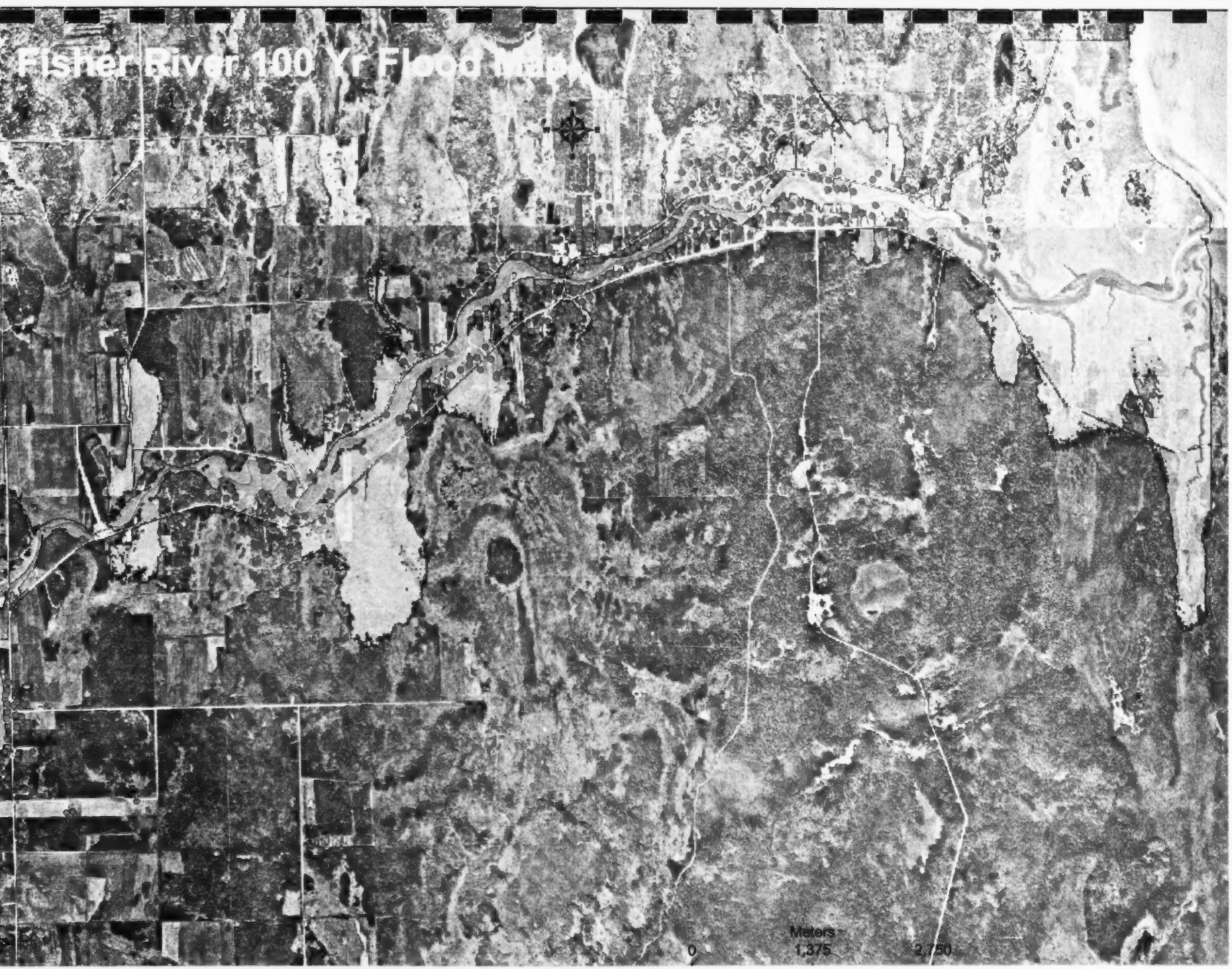

Peguis 100 Yr Flood Map with Diversion

Fisher River 100 Yr Flood Map
with Diversion

Meters
0
1,375
2,750


Simulated 100 Year Flood with Diversion
Legend
watershed-outline
mb-road-clip
watercourses
fisher-house-080212
pequis-house-080324
Proposed Diversion Ditch
100y Flood with Diversion
<0.15
< 0.25
<0.5
< 0.75
< 1
<1.25
<1.5
<1.75
< 2
>2
N
W
E
S
0 2 4 8 Kilometers

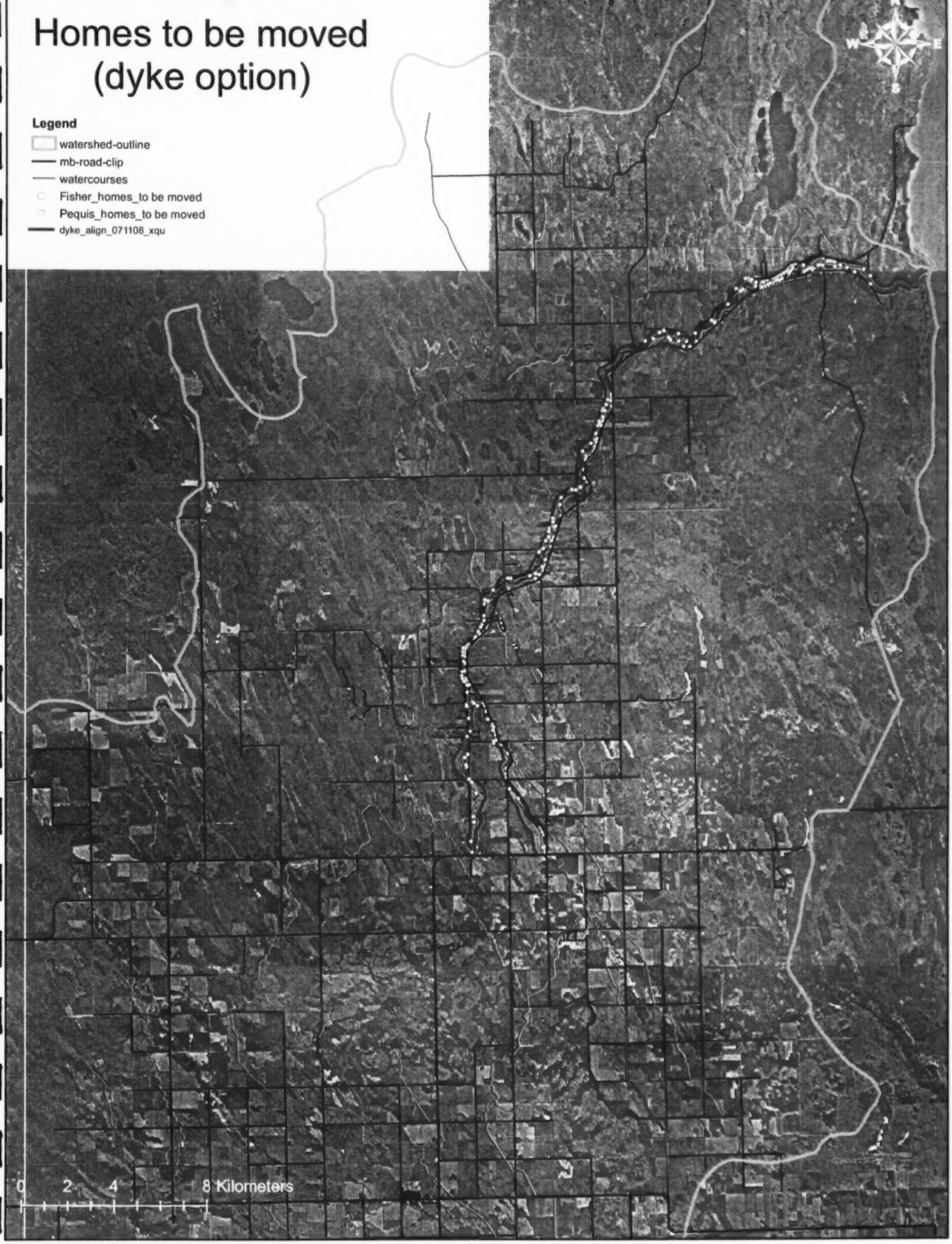

Peguis 100 Yr Flood Map
0
1,200
2,400


Fisher River 100 Yr Flood Map
Meters
0
1,375
2,750

Homes to be moved (dyke option)

Legend

- watershed-outline
- mb-road-clip
- watercourses
- Fisher_homes_to be moved
- Pequis_homes_to be moved
- dyke_align_071108_xqu



Appendix B

Community Presentation Response Summary

Appendix B

Community Presentation Response Summary

APPENDIX B

Fisher River Watershed Hydrodynamic Model and Economic Analysis Study - Community Presentation and Response

1. Background

Long-standing flooding issues in Fisher River Cree and Peguis First Nations triggered Manitoba Water Stewardship (MWS) and Indian and Northern Affairs Canada (INAC) to enter into an agreement to study the causes of and potential solutions to the flooding problem. AECOM was commissioned to undertake a comprehensive study of flooding issues in the Fisher River Watershed. The study included the collection of LiDAR (light detection and ranging) survey data, field data, and the application of hydrologic and hydraulic models. An economic analysis was also conducted to determine cost effective flood mitigation options for the two communities.

The study looked at:

- The causes of flooding
- The impact of changes in land drainage and land use on flooding
- The 100-year flood plain
- The effectiveness of various measures to restore and enhance the river's hydraulic capacity
- The economic effectiveness of various flood controls

This study was initiated to assist decision-makers in addressing the long-standing flooding issues on the Fisher River Cree and Peguis First Nations. A key component of this study was to involve and dialogue with the impacted communities. One community involvement tool implemented throughout the study was the development and involvement of a Technical Advisory Committee (TAC). The TAC was made up of representatives from Fisher River Cree and Peguis First Nations, government, and local communities. The TAC was involved in various aspects of the study from the review of Terms of Reference for the AECOM study, LiDAR data collection, review of the models and results, and flood damage assessment.

In order to involve and collect the perspectives of the larger community, public meetings were held on January 8, 2009 in Fisher River Cree First Nation and on January 13, 2009 in Peguis First Nation. The objectives of the community meetings were:

- To share with the communities the context of the study and the process used to conduct the study.
- To provide the communities with the results of the Fisher River Flood study conducted by AECOM.
- To obtain and understand the community perspectives on the conduct and results of the study.

At the end of each meeting, participants were offered the opportunity to submit further comments to Sheldon McLeod or Jennifer Prochera. No additional comments were

received. This report describes the input received during the meetings and in the informal discussion with community members immediately following the meeting.

The Management Committee was also presented with a letter which the Peguis Chief and Council had received, written in July 2008, describing the need for maintenance of existing drains to enable the local farmers to get the accumulated water off their lands, preserving hay and other crops and significantly affecting the viability of their operations. The needs described in the letter and the resultant proposals bear significantly on many of the comments heard during the Peguis community meeting held as part of this project. A copy of this letter and attachments can be found are in Attachment A.

2. Fisher River Community Meeting Approach and Results

The Fisher River Community Meeting/Open House was held on January 8, 2009 at the Fisher River Community Hall. Two meetings were scheduled one in the afternoon and one in the evening. Before the meeting began community members were invited to view the story board display, familiarize themselves with the study and ask preliminary questions.

The meeting was opened by Chief David Crate and began with an opening prayer by an Elder. The meeting was attended by 24 participants, with a few additional community members flowing in and out of the meeting as it progressed. The format and expectations of the day were outlined by the meeting facilitator Sheldon McLeod. Presentations were made to the community. The first was by management committee member Steve Topping of Manitoba Water Stewardship (MWS) who provided a summary of the events that led to the development of the study. The second presentation was given by Eric Blais of AECOM who described the results of the study. Community members were given the opportunity to ask for clarification and further explanation throughout the presentations.

After the presentations were completed community members were invited to provide their thoughts on what was presented and to ask questions. The comment and questions section of the meeting lasted until participants had no additional comments they wished to express. At the close of the meeting, Chief Crate summarized the importance and context of the study. Closing statements were also made by management committee members Steven Topping and Ron Payne. The meeting was then closed with a closing prayer led by an elder.

The evening meeting had only two community members present. This was due in part to the attendance of the afternoon session having included those with the greatest interest and because of competing events in the community. Due to the small attendance the evening meeting was adjusted. The formal presentations were not given and instead members of the AECOM technical team toured the story board display with each of the attendees explaining the study and allowing them ask questions and provide comment in a one-on-one setting.

To simplify the presentation of the results from the Fisher River community meeting the comments, questions, and concerns of community members have been divided into the following categories:

- Changes to the Fisher River as Observed by Community Members
- Comments on Presented Flood Mitigation Options
- Future Development and Next Steps

Changes to the Fisher River as Observed by Community Members:

Community members made the following comments about the river and how it has changed over time:

- I used to drink from the river and swim in it, you can't do that now. It's not safe. My people haven't been able to use the river like that since I was a child.
- After they took out the rapids the flooding was worse.
- I have noticed that areas of the river are a lot shallower than they used to be.

Comments on Presented Flood Mitigation Options:

Various flood mitigation options were modelled within the study to analyze the reduction of flooding to the affected communities. The mitigation methods studied include: diversion; dyking; temporary storage upstream; and increasing the Fisher River's hydraulic capacity by replacing existing low-level crossings, cleaning-out of gravel from frequent culvert wash-outs, and partial removal of select natural rapids.

A large percentage of the questions and comments made revolved around low level crossings and the recommendation of the consultants to install several low-profile Box Culverts. During the presentation a few questions concerning the performance of Box Culverts were asked. It was explained that the capacity and durability of Box Culverts means that the crossings would have a greater ability to withstand large flow events without loss to the structural integrity of the crossing and without a washout. The existing culverts frequently wash out and deposit sand and gravel downstream reducing the capacity of the main channel. The new crossings would enable earlier restoration of service when a crossing is flooded and result in less environmental damage from washouts. While there was support from attendees for the use of Box Culverts in the flood mitigation strategy, concern was expressed about the use of this infrastructure at the Old Koostatak Crossing. Community members felt that a bridge would be more appropriate at this crossing and brought up several concerns in relation to the installation of a Box Culvert system instead of a bridge at this crossing. Their main concerns with the installation of an eight-box Box Culvert system at the Old Koostatak crossing revolved around debris, ice, impact to fish migration, wind swells from the lake, and road closures during extreme events.

Several community members brought up the concern of wind swells from the lake. The Old Koostatak crossing is currently impacted from both river flooding and water from the lake. A community member asked if the drawings take into account the back up experienced 2-3 times a year from the wind off the lake. The response from AECOM

was that it was not, because during the time of year a 100-year flood event would occur the lake would still be frozen and wind set-up would not occur. Another community member added that a bridge was still their preferred option at this crossing as it is an important access route for the community and the surrounding areas and that he was concerned that the crossing would still be under water during flood events impacting access to services and leading to traffic being rerouted and causing damages to other infrastructure.

When the benefit-cost ratios of the flood mitigation options were discussed a member of the community commented that money was found for the diversion around Winnipeg and the floodway expansion. The response was that the benefit-cost ratio is greater than 1 in the case of the Red River Floodway whereas this study showed the benefit-cost ratio for the diversion option on the Fisher River to be 0.16. Another community member responded:

> *"We prefer a bridge, there was a study before, I was on Council at the time. Back then the bridge was $30,000. Government can find the money, the building cost will just get more expensive, and so will the damage costs we incur each time the crossing is out. This year the crossing was out 3 times. Now it costs more to build a bridge but the cost shouldn't matter and the recession should not be used as an excuse. Money shouldn't be a factor. I'm glad the study was done but now something has to be done."*

Future Development and Next Steps:

A number of community members brought up the issue of land use and future community development expressing the concern that they have very little acceptable land for growing crops and building houses and that this needs to be taken into account when examining flood mitigation issues. As one community member stated:

> *"If you need to move houses for the dyking option where will you move them? The larger land use plan of the community will need to be taken into consideration...We need long term flooding solutions that make the land more usable."*

Community members also expressed a need for assurance that that the study would move beyond investigating the options to implementing effective long-term solutions that would benefit the community. It was also clear that attendees felt at there was a need for collaboration and coordination as the different flood mitigation projects and community land use plans are implemented on the ground to insure the different initiatives will be complementary. A representative of Dallas/Red Rose also emphasized the need for a coordinated approach on the part of the communities in taking this further with the Management Committee.

3. <u>Peguis Open House Approach and Results</u>

The Peguis Community Meeting/Open House was held on January 13, 2009 at the Peguis Community Hall. Two meetings were scheduled one in the afternoon and one in the

evening. Before the meeting began community members were invited to view the story board display, familiarize themselves with the study and ask preliminary questions. A distinctive feature of this meeting was its simultaneous broadcast on local radio which enabled some citizens to attend later portions of the meeting after having listened to earlier parts on the radio.

The meeting was opened by Chief Hudson and began with an opening prayer by an Elder. The format and expectations of the day were outlined by the meeting facilitator Sheldon McLeod. Three presentations were made to the community. The first was by Management Committee member Steve Topping of MWS who provided a summary of the events that led to the development of the study. The second presentation was given by Chief Hudson and Councilor Cochrane as local representatives of the Technical Advisory committee, and focused on the importance and context of the study. The third presentation was given by Eric Blais of AECOM who provided the results of the study. Community members were given the opportunity to ask for clarification and further explanation throughout the presentations.

After the presentations were completed community members were invited to provide their thoughts on what was presented and to ask questions. As the afternoon generated considerable comment, Chief Hudson and Councillor Cochrane decided that instead of having an additional evening open house the afternoon session would be extended through the supper hour. This was seen as a logical choice as many of the new participants that were arriving had heard the presentations on the radio earlier in the afternoon. There were approximately 45 people in the room at all times. However, the attendance would have been much higher than 45 as the meeting had turned into a come and go event with a continual influx of people. The meeting continued for over five hours in total. The meeting was then closed with statements from Management Committee members Steven Topping and Ron Payne, Technical Advisory Committee members Chief Hudson and Councilor Cochrane, and a closing prayer led by a community elder.

To simplify the presentation of the results from the Peguis community meeting, the comments, questions, and concerns of community members have been divided into the following categories:

- Changes to the Fisher River as Observed by Community Members
- Health and Safety
- Impact on Quality of Life
- Overland Flooding
- Land Use
- Drainage
- Compensation
- Comments on Presented Flood Mitigation Options

Changes to the Fisher River as Observed by Community Members:

Committee members made several observations about the river and how it has changed over the years. As one community member expressed:

> *"You can do many studies but it is us who know the history. The studies need to be compared to what we know and what we see on the land."*

Community members made the following additional comments about the river and how it has changed over time:

- I used to be able to see the bottom of the river. I could look through the ice and see to the bottom.
- The River used to be able to handle the flow. Now it bottle-necks.
- In 1971 and 1972, I was drinking and swimming in the River. In 1974, you could no longer drink the water or swim in it.
- I remember my dad catching rainbow trout in the river. Now there are just suckers and carp in the river.
- The level of Lake Winnipeg is rising and this is impacting the flooding.
- We get flooded from both sides - the river and the lake.
- Along road 325 at the first bridge if you look by the beaver dam you can see the pollution, the algae sludge, and bacteria in the ditch.
- Taking out the rapids north of here did not help with flooding.
- The brush tends to grow back thicker than it was before clearing.

Health & Safety:

Health and safety concerns were brought up several times. Examples of some of the comments made concerning health and safety include:

- Mould is a huge problem; there are over 400 homes with mould.
- There are elders with breathing problems probably related to the occurrence of mould.
- The crossings along escape routes need to be bridges. This will also help other communities. For example, Fisher River would benefit from this.
- Several traditional medicines are now difficult to find or access. (Weecase, sweet grass, wild ginger, spruce bark, plantain, and bulrushes were all mentioned)

Impact on Quality of Life:

Throughout the course of the meeting several community members shared their own experiences and struggles with flooding. It is clear, from listening to Elders and other community members share their stories, that the decades of flooding has had an acute and long-lasting impact on the quality of life of those living within the community. Community members described their experiences and the stress of living through:

- Loss/damage of property
- Difficulty in receiving compensation for loss of property
- Overcrowding as a result of flooding
- Having lived in more than one house that has flooded

- Health impacts as a result of mould and other contaminants
- Evacuation
- Contamination of wells
- Disruption of life
- Being cut off from essential services due to road washouts

Drainage:

A key component of the study was to assess the causes of flooding and to determine if drainage in the area has a significant impact on flow. Through the use of detailed hydrologic and hydraulic modelling the study concluded that drainage does not have a significant impact on peak water levels or flood duration for extreme events at downstream locations. Community members had difficulty with this conclusion as the message seemed to be in conflict with their experiences with flooding. As one community member expressed:

"it seems to defy logic to say the drainage ditches don't affect us."

Another, community member referenced previous studies (Hydrotek 1982 and Trident 1983) that looked at the flooding situation prior to the opening of the drains in the 1970. All previous studies were reviewed when undertaking the current study - AECOM described the studies referenced as very cursory and Management Committee member Steve Topping explained that the current study was the first study that looked at the causes of flooding and solutions from a technical engineering perspective.

Community members described summer events that behaved like spring events and believe them to have a direct correlation with drainage. As one community member explained "After a large rain there is flooding the next day. How is that not a result of the water coming from the South? It feels like the 700 miles of drainage has an effect." The response was that the study looked at extreme floods to see if the drainage that occurred impacted the intensity of the flood. Natural climatic conditions have had an impact on flooding conditions. The 1970s were a wet period and that caused more flooding than had been observed in the previous decade. A couple of community members recommended the impact of drainage on overland flooding be studied and taken into consideration during the evaluation of flood mitigation options.

One attendee commented that there appeared to be a new drain by the new highway and asked who to call if they suspect a drain is illegal. Management Committee member Steve Topping answered that if an illegal drain is suspected it should be reported to MWS and that it would then be investigated by a water resource officer. He further explained that drainage development is legislated by the Water Rights Act and all proposed drainage changes that alter the natural flow require a license. Under the Act, Peguis would be consulted on the establishment of any new drains. The new model developed during this study can now be used when evaluating changes in water flow.

Overland Flooding:

Not all flooding experienced within the community is related to river flooding. Several community members described being impacted by overland flooding and expressed that it appears to have gotten worse in recent years. The study addressed the flooding from the river and did not address local overland flooding. Several comments were also made about the water table being higher and the impact that this is having on drinking water and the severity of floods. The impact of overland flooding on community farmers was also discussed. Farmers have experienced delays in spring seeding of crops and limited crop yield as a result of overland flooding. It is felt that drainage from the South is having an effect on overland flooding and that further studies are needed to explore this link.

Land Use:

A number of community members brought up the issue of land use and future community development expressing that they have very little acceptable land for growing crops and building houses and that this needs to be taken into account when examining flood mitigation issues. One community member also expressed his concern that the community needed to remember to be mindful of how land is developed.

> *"We also have to look within the community the culverts that were put in do not drain the land properly. We can point the finger at the outside but we have to always look at what we are doing. This is a problem that didn't happen recently we have to look at how we are putting in culverts and developing land there were some new house just built that were put in the flood zone. We have to work with the study and not build in the flood zone. I hope we put in proper culverts so we can use the land again."*

Compensation:

Concerns were raised in relation to compensation for damaged property. INAC will not pay for removable items in the basement. Community members expressed that it can be difficult to remove items from the basement because many homes are over-crowded and have family members living in the basement. Another community member described coming home to a flooded basement after being out of town when the warning to remove items had been given.

Comments on Presented Flood Mitigation Options:

Various flood mitigation options were modelled within the study to analyze the reduction of flooding to the affected communities. The mitigation methods studied include: diversion; dyking; temporary storage upstream; and increasing the Fisher River's hydraulic capacity by replacing existing low-level crossings, clean-out of gravel from frequent culvert wash-outs, and partial removal of select natural rapids.

The construction of ring dyke like the one in Emerson was raised by a community member. It was explained that ring dykes are only viable when communities have a high population density. The funding breakdown used in the Emerson example was also explained.

Community members made comments on the removal of natural rapids stating that in the past when this had been done it did not appear to reduce flooding. Concerns about the lack of usable land and the question of where homes would be moved if a dyke was constructed was introduced when the different flood mitigation options were discussed. The desire to involve community members in the construction associated with flood mitigation and putting in place training programs was also expressed.

Another community member asked why the floodway option was not considered viable. The response given was that the model showed that a floodway would have an impact on flooding where the water was taken off but wouldn't make a significant difference to the flow further downstream. In addition, the channel built would need to be very large making the price of a floodway significantly greater than the benefit.

4. Conclusion

The following are key themes which emerged either at one of the meetings or at both of the meetings. The reader will note from these key themes that discussion focused on community concerns which sometimes aligned with the mitigation options provided and sometimes did not. Thus, no consensus emerged regarding any of the mitigation options. Rather, comments were made that the diversion option had been dispensed on the basis of cost too quickly and not enough thought had been given to where homes could be re-located to with the dyking option.

Summary of Key Themes (Both Communities)

- The narrowness of the scope of the study which was only to examine flooding of the Fisher River was not easily grasped in either community and seemed incongruous to many. For local residents, the flooding issue is much larger and more frequent than the scope covered in the study.
- Residents in both communities have observed many changes in the river, many of which they feel are correlated with increased upstream drainage. These observed changes included decreased water quality (contaminants and turbidity), shallower depths in certain river cross-sections, and increased dominance of rough fishes in the river, among other things.
- Flooding often results in families being cut off from essential services due to road washouts.
- Both communities would prefer to see infrastructure choices which would reduce annual damages and frequent interruption of access and services.
- The communities were appreciative of the opportunity to discuss the report and related issues and look forward to ongoing engagement as the topic evolves.

Summary of Key Themes (Fisher River)

- The community's preference is for a bridge at the Old Koostatak crossing and Box Culverts at the other low-level crossings.
- There is a strong desire to see progress made on the flooding issue leading to long-term solutions being put in place.
- The community would like to see solutions that enhance the usability of the land for both farming and community development.
- There is a need for collaboration and coordination as the different flood mitigation projects and community land use plans are implemented on the ground to ensure the different initiatives will be complementary.

Summary of Key Themes (Peguis)

- The community experiences different types of flooding. Local overland flooding is a significant problem. There is a resultant desire for a study which would examine drainage and overland flooding in the community.
- There has been considerable difficulty in receiving compensation for loss of property.
- There are significant health impacts as a result of mould and other contaminants.
- There is a concern about the lack of usable land, leading to the question of "where do we go if we have to move our homes?"
- There are substantial impacts of the local flooding on farmers in the area.
- The community wishes to see opportunities maximized for the involvement of community members in the construction related to the implementation of flood mitigation measures. This should also extend to training programs.

ATTACHMENT 1 Fisher River Watershed Community Presentations

July 22, 2008

Chief and Council
Peguis First Nation
Peguis, Mb

Dear Chief and Council

Re : Request from Peguis Farmers for assistance

Two years ago, a plan was put in place by the Council to start cleaning ditches in Peguis of willows and grass build up with a backhoe so that the water could easily flow out of the ditches. This plan has not yet been started and after heavy rains of this summer the water remains sitting in the fields. Many crops and hayfields are flooded. Photos of a few of these fields are included. These photos were taken on July 21, 2008. Most of these photos were taken from the road, showing the water overflowing from the ditches into the fields.

Some farmers have cattle that are only able to graze on hills and are often up to their bellies in water trying to eat the tops of the grass. Hay fields remain flooded, making it impossible to cut and bale hay needed for the coming winter. Most Peguis farmers will not be able to make the hay that they require for their cattle over the winter. We will have to buy hay at a much greater expense than doing it ourselves. Hay will likely be scarce in the area making it even more expensive to purchase and the expense of brining it in will also be high because of the cost of fuel.

We are requesting financial assistance to buy the needed hay. Without assistance, some farmers may be forced to sell some, or even most of their cattle, possibly ending their farming business. It will also be difficult to make loan payments with this added expense, also putting farms in jeopardy. This would be a great loss to the community of Peguis.

Thank you for taking this request into consideration.

Sincerely,

Wallace Stevenson, President
Peguis Farming Committtee

Darryl Bear, Vice President
Peguis Farming Committee

ATTACHMENT 1 Fisher River Watershed Community Presentations

Peguis Farmer Producers	2008						
Bear Darryl/Bruce	cattle/crop 1000 acres	150-head	80 calfs-feeders	$50.00-per bale	1500-bales required	includes freight	45000
Bear Oliver	cattle/crop	36-head		$50.00-per bale	900-bales required	includes freight	25000
Bear Cheryl/Eric	cattle/crop	20-head	12-calfs	$50.00 per-bale	300-bales required	includes freight	15000
Cochrane Dean/Nicole	cattle/crop	170-head	100 calfs	$50.00 per bale	1200-bales required	includes freight	60000
Favel Gerald(booger)	hay -produ 300 acres			$50.00 per bale	500 bales producer	includes freight	25000
Flett Jack	hay -produ 500 acres			$50.00-per-bale	500-bales producer	includes freight	25000
Hudson vince	cattle/crop	90-head	22-calfs	$50.00-per-bale	300 bales required	includes freight	15000
Hudon alex	hay -produ 200 acres			$50.00-per-bale	300 bales producer	includes freight	15000
Stevenson Wally	cattle/crop 500 acres	180-head	100-calfs	$50.00-per-bale	1500-bales required	includes freight	75000
Stevenson derby	cattle	25-head	15-calfs	$50.00-per-bale	250-bales required	includes freight	12500
stevenson brian/karen	cattle	80-head	50-calfs	$50.00-per bale	800-bales required	includes freight	40000
Stevenson Donald	crop/hay 400 acres			$50.00 per-bale	400-bales producer	includes freight	20000
Stevenson glen	crop/hay 400 acres			$50.00-per-bale	400-bales required	includes freight	20000
Thomas Barry	cattle	20-head	12-calfs	$50.00-per-bale	250-bales required	includes freight	12500
Watt ranb	horses	10-head		$50.00-per-bale	100-bales required	includes freight	5000
						includes freight	440000

ATTACHMENT 1 Fisher River Watershed Community Presentations

Peguis First Nation
Drainage Plan

Effective flood control and storm drain activities are critically important for any sound water resource system. Taking correct action will help safe lives, mitigate devastating damage and protect assets. The importance of proper surface and sub-surface drainage and the development of a good overall maintenance plan for field drainage cannot be over stressed. Both of these will save money, provide better community enjoyment, and add to the life of the land. Peguis First Nation has determined that a proper drainage plan needs to be developed for community. With Chronic Flooding every Spring, and flash rainstorms, leaves the reserve susceptible to overland flooding. With no real work done on the drains in the past 20 years, the drains have are overgrown with small trees and shrubs. Agriculture drainage is a major concern for the local farmers that face flooding every year, there are unable to get into their fields to put in their crops, most times until it is to late to plant a crop.

The Peguis First Nation Public Works Department, Peguis Development Corp. and Peguis Training and Employment have worked together to develop a drainage plan for the first 36 miles of drainage work.

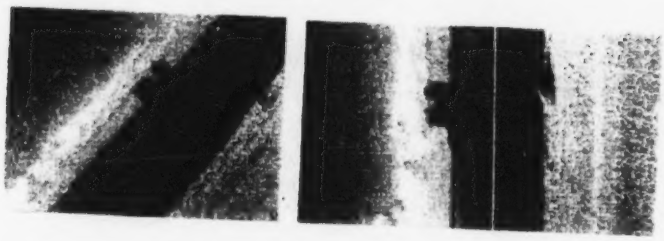
With a proper drainage plan, and work to be completed in phases, the flooding will be minimized.

ATTACHMENT 1 Fisher River Watershed Community Presentations

Peguis First Nation
Drainage Plan

Start
Steven & Geraldine Heinrichs
Section 10 & 11, in between the sections – 1 mile - completed

Continuing on to Section 15 – 1 mile



Then on to Section 22, located between 22 & 23 – 1 mile

Then on to Section 27, between 26 & 27 – 1 mile

Then go on to Section 28, in the middle of section 28, - Bryan Cochrane 1.5 miles
***Culvert needs to be replaced.
24" x 36' culvert &
2 couplers

Then go through the southwest section of 33, up to the school road. - .5 miles

Then go to Jack Flett Section 15, 27 1 W Start in section 15 then go on to the road Allowance of section 22 and then straight north to the river – Jack Flett – 1.5 miles
**Suggest to replace the old culvert with a bigger one. 24" x 36'
36" x 36' Culvert
2 couplers

Come back to Section 15 then go North through Section 22 we will finish at the road allowance North of 22 – Jack Flett – 1.5 miles

Then go to SW Section 23 27 1W – Glen Stevenson - .5 miles

Then go to NW Section 14 27 1W – Dennis Bear - .5 mile
**Suggest to replace the old culvert with a bigger one. 24" x 36'
36" x 36' Culvert
2 couplers

One option is to continue on to clean out Robert Bear's creek:
Then go to Section SE corner of 27, go north up into section 26, keep going north into the River up into section 35, where it ends at the river. – 2 miles

Or move the excavator to

Start from the River in River lot 26, work our way up into section 20, go all the way through section 20 and then into 29, right north up into section 32, between 31 & 32. – 3.5 miles Wallace Stevenson

From there we come back to section 30

Come back to NE corner of 30, then do the north perimeter of 30, then go down through 25, end of the beginning of 24, then go east to middle of 30, then go North through the middle of section 30. – 3 miles

Then go east and do the North perimeter of 29. – 1 mile

Then go to North perimeter of 28, go east ½ mile, then go north into Fred Stevenson creek. – 1 mile

Then go onto to Section 33 and do the three ditches that are in that area. – 3 miles
Donald Stevenson

Then go into SW corner of Section 4, 28 1w, goes into NE section 5, then go north into section 8, then come west to section 7. – 3 miles

Then go back to middle of section 8 and go North to end at the main road. – 1 mile

Other Considerations should be given to areas:
Start at section 24, 26 2 w, go north through 25, then go north through to section 36, then go through section 18, 27 1w, down through riverlots 26 & 27 to the river. – 5 miles
Need culvert in section 35, 26 1 W
Levels need to established between Section 25, 36, & 13, north along the road.
After levels are established, drainage needs to done between section 24, 25, 36 and 13.
- 4 miles

ATTACHMENT 1 Fisher River Watershed Community Presentations

Southwest 20. 26 1 w. River lot 56, Cyril Spence 8th of a mile

Peguis First Nation
Drainage Plan
Budget

Costs for Excavator:
40 hrs = 3 miles possibly more
$900/ week
$300/tank – tank up 3 times per week
Operator – $480 plus benefits @12% for 40 hrs
Excavator – $120/hour

Total amount of miles for the following plan: 36.5/8 Miles

Excavator
Assumptions do 3 miles per week = 12 weeks of work = 36 miles after 12 weeks

Fuel & oil -	$900/week x 12 weeks =	$10,800.00
Labour -	$540.00 x 12 weeks =	$ 6,480.00
Contingency		$ 1,974.00
Total Costs		$19,254.00

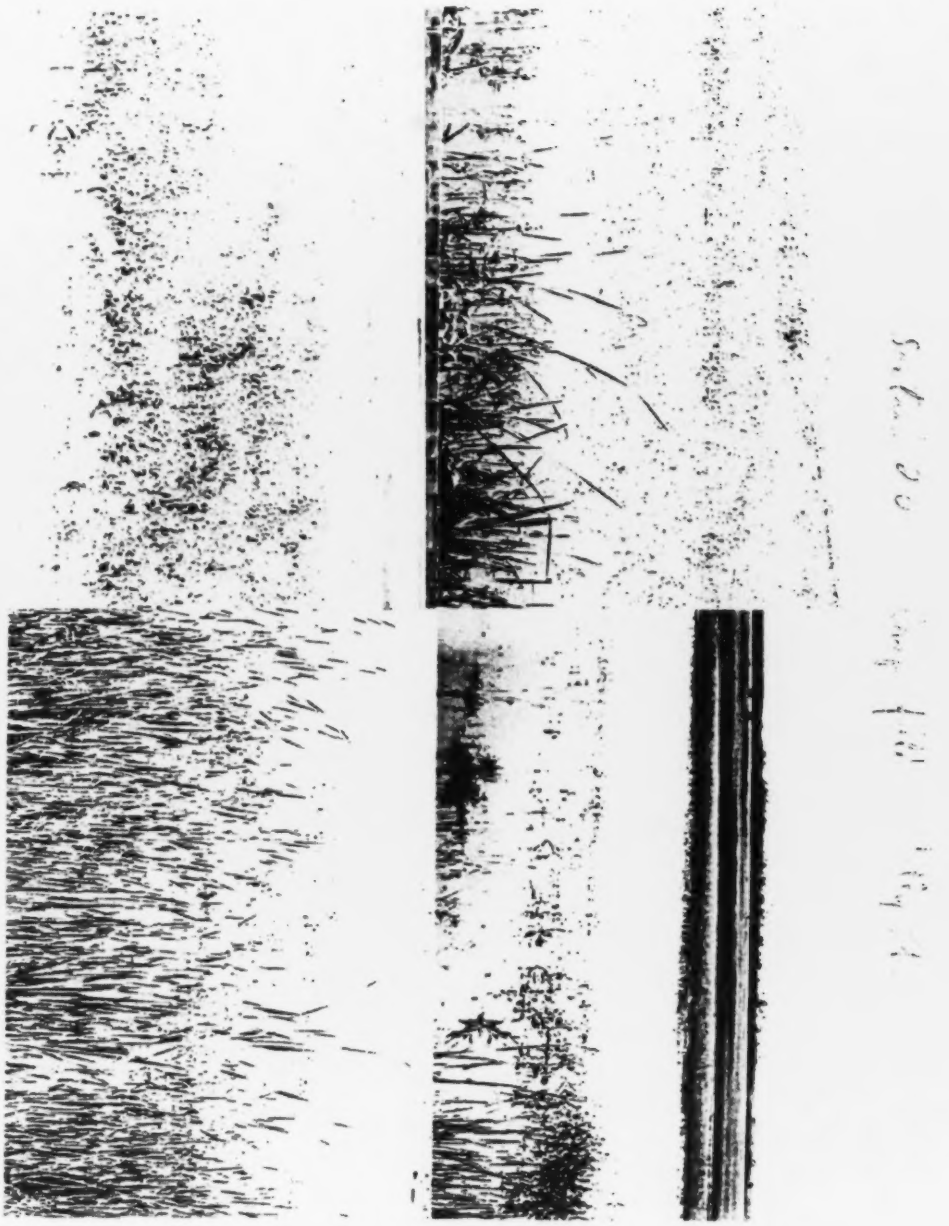
Labour
7 hrs/day x 5 days/week for 4 weeks = 140 hrs/4 wks/man

3 Foreman	140 hrs x $10/hr.	3 x 140 hrs x $10/hr.=	$ 4,200.00
30 Labourers	140 hrs x $9/hr.	30 x 140 hrs x $9/hr. =	$37,800.00
3 Sawyers	140 hrs x $12/hr.	3 x 140 hrs. x $12/hr. =	$ 5,040.00
Benefits for workers: total labor costs $47,040.00 x 12% =			$ 5,645.00
Start up supplies for saws (gas, oil, filters)			$ 260.00
			$52,945.00

In Kind Contributions
Excavator: $120/hrs x 12 wks x 40 hrs/wk = 480 hrs x $120 $57,600.00

Total Real Costs	$19,254.00 + $52,945.00 =	$72,199.00
Total Project Costs	$72,199.00 + $57,600.00 =	$129,799.00

ATTACHMENT 1 Fisher River Watershed Community Presentations



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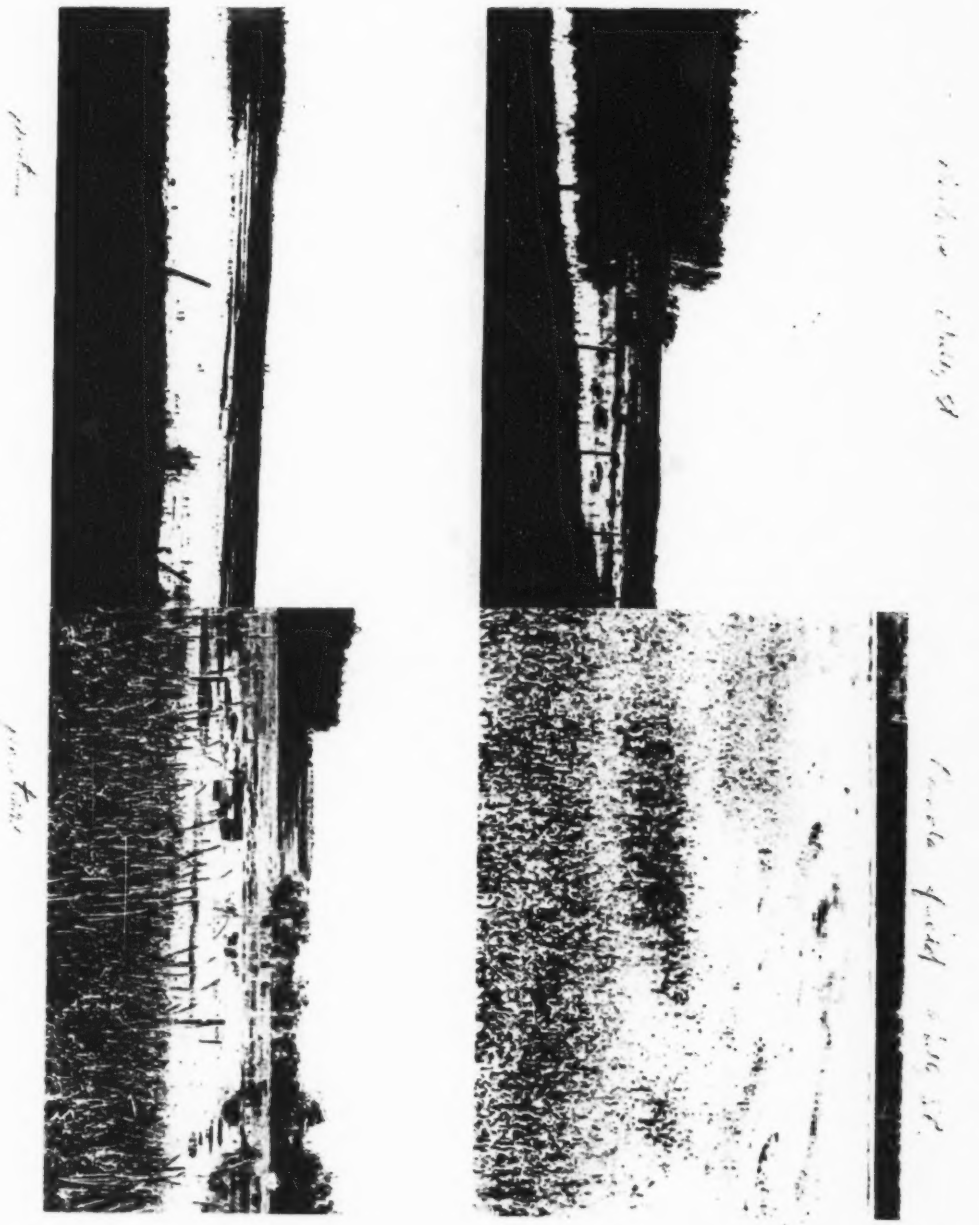
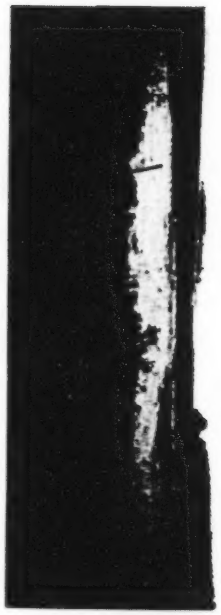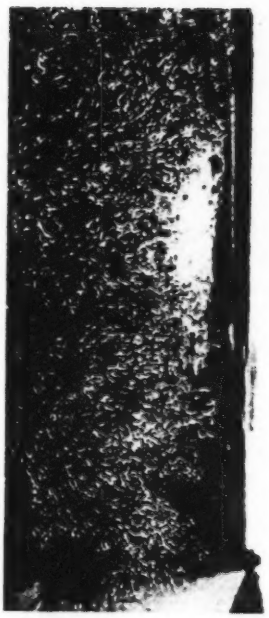
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